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The sad tidings of the death of Dr. Stoliczka will have spread to many and distant lands before this brief record can be published. Among naturalists everywhere it will be felt that a man of distinguished merit and of very high promise has been prematurely lost to science. To the Geological Survey of India that loss is in a manner irreparable. In the large and ever increasing world of naturalists the disappearance of even a foremost man is only felt through reflection; it is among his immediate colleagues and in the scene of his labors that the loss of such an one falls as a very present calamity. To those who have known and worked with Dr. Stoliczka his early death will be a life-long regret.

Dr. Stoliczka's career commenced on the staff of the Geological Survey of Austria. Since 1862 he has been palæontologist to the Geological Survey of India, in which capacity he was chiefly engaged upon the Palæontologia Indica. By singular good fortune his work in that publication has been left in a very finished state. Only just before starting with the mission to Kashgar he had issued the last number of the series descriptive of the Cretaceous Fauna of Southern India, completing four large 4to. volumes. This work will form a lasting monument of Dr. Stoliczka's power as a naturalist.

His numerous contributions to several branches of Zoology do not call for mention here; but special notice must be taken of his work as a Geologist in the field, and which, as unfinished, might escape the attention it deserves. That the summits and plateaus of the Tibetan region are formed of stratified rocks representing palæozoic, secondary and tertiary formations, had long since been determined by several explorers. Stoliczka was the first to give an adequate sketch of the sequence and range of those deposits. His description of them, in the fifth volume of the Memoirs of the Geological Survey, the result of two trips made in the summers of 1864 and 1865, will form the safe basis of all future work in those regions. No one but an accomplished palæontologist could have achieved such results in so short a time. This work was an essential preliminary to the full geological study of that difficult ground.

The completion of his Himalayan work was what Stoliczka had most at heart. His enthusiasm for it has cost him his life. In the spring of last year he had made arrangements for a visit to Europe, where no doubt a worthy reception awaited him; but when he heard of the projected mission to Kashgar, he eagerly offered himself as naturalist to the expedition. Those who knew how he had felt the rigours of the mountain climate on the occasion of his last visit, and who appreciated the value of his life, tried to dissuade him from going, but with no effect. In crossing the passes in October he had an acute attack of spinal meningitis; but he rallied, and was able for active work for the rest of the journey, even for the trying detour over the Pamir in April. It was in crossing the Korakoram on the 16th of June that he felt the first return of the fatal disease,—this time in his neck and head. Still even on the 18th he was able during the march to make observations on foot. That evening he fell into a semi-unconscious state, and remained so till he died about noon on the 19th. His remains were interred with all honours by the officers of the mission, his fellow travellers, on the 23rd, at Leh.

In letters received from him, dated the 12th, he wrote disparagingly of the geological work he had been able to accomplish, the ground having been for the most part deeply covered by snow. He had probably already given us all the leading features in the several papers that have been published in our Records. Of the rare zoological collections he had made he wrote with great satisfaction.

Dr. Ferdinand Stoliczka only attained the age of 36 years.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1874. [August.

GEOLOGICAL OBSERVATIONS MADE ON A VISIT TO THE CHADERKUL, THIAN SHAN RANGE, *by* DR. F. STOLICZKA, *Naturalist attached to the Yarkand Embassy.*

After a stay of nearly a month in our embassy quarters at Yangishar, near Kashgar, the diplomacy of our envoy secured us the Amir's permission for a trip to the Chaderkul, a lake situated close on the Russian frontier, about 112 miles north by west of Kashgar, among the southern branches of the Thian Shan range. Under the leadership of Colonel Gordon, we—Captain Trotter and myself—left Yangishar about noon on the last day of 1873, receiving the greeting of the new year in one of the villages of the Artush valley, some 25 miles north-west from our last quarters. On the 1st of January 1874 we marched up the Toyan river for about 20 miles to a small encampment of the Kirghiz, called Chung-terek; and following the Toyan, and passing the forts Murza-terek and Chakmák, we camped on the fifth day at Turug-at-bela, about 11 miles south of the Turug pass, beyond which, five miles further on, lies the Chaderkul. On the sixth we visited the lake, and on the day following retraced our steps, by the same route we came, towards Kashgar, which we reached on the 11th January.

Having had a shooting day at Turug-at-bela, and one day's halt with the King's obliging officers at the Chakmák fort, we were actually only nine days on the march, during which we accomplished a distance of about 224 miles. It will be readily understood, that while thus marching, there was not much time to search for favorable sections in out-of-the way places; but merely to note what was at hand on the road. I can, therefore, only introduce my geological observations as passing remarks.

Leaving the extensive löss-deposits of the valley of the Kashgar Daria, the plain rises very gradually towards a low ridge, of which I shall speak as the Artush range. It is remarkably uniform in its elevation, averaging about 400 feet, somewhat increasing in height towards the west and diminishing towards the east, which direction is its general strike. This range separates the Kashgar plain from the valley of the Artush river, which cuts through the ridge about eight miles nearly due north of the city. Viewed from this, the entire ridge appears very regularly furrowed and weather-worn on its slope, indicating the softness of the material of which it is composed. One would have, however, hardly fancied, that it merely consists of bedded clay and sand, mostly yellowish white, occasionally reddish, and sometimes with interstratified layers of greater consistency, hardened by a calcareous or silicious cement. On the left bank, in the passage of the river through the ridge, the beds appear in dome-shape, gently dipping towards the Kashgar plain on one side, and with a considerably higher angle into the Artush valley on the other. On the right bank at the gap all the

exposed beds dip southward, those on the reverse of the anticlinal having been washed away by the Artush river up to the longitudinal axis, and thus exposing almost vertical faces. These remarkably homogeneous, clayey and sandy beds may appropriately be called *Artush beds*, and although I could nowhere find a trace of a fossil in them, it seems to me very probable that they are of marine origin and of neogene age.

The southern slopes of the ridge are on their basal half entirely covered with gravel, which in places even extends to the top, assuming here a thickness of from 10 to 15 feet. Locally the gravel beds are separated from the main range by a shallow depression, forming a low ridge which runs along the base of the higher one, and from which it is, even in the distance, clearly discernible by its dark tint. The pebbles in the gravel are mostly of small size and well river-worn; they are derived to a very large extent from grey or greenish sandstones and shales, black or white limestone, more rarely of trap, basalt, and of gneiss. With the exception of the last-named rock, all the others had been met with *in situ* in the upper Toyan valley. The pieces of gneiss belong to a group of metamorphic rock which is usually called *Protogine*. It is mainly composed of quartz and white or reddish orthoclase, with a comparatively small proportion of a green chloritic substance. The white felspar variety generally contains as an accessory mineral schorl, in short, rather thick, crystals. I shall subsequently allude to the probable source from which the protogine pebbles might have been derived.

From Artush we marched, as already stated, northwards, up the Toyan river, and for the next 22 miles one was surprised to find nothing but the same Artush—and gravel—deposits, the former constantly dipping at a high angle to north by west, and the latter resting on them in slightly inclined or horizontal strata; while among the recent river deposits in the bed of the valley itself the order of things appeared reversed. The gravels, having first yielded to denudation, were here underlying the clays derived from the Artush beds, thus preparing an arable ground for the agriculturist, whenever a favorable opportunity offered itself. A few miles south of Chungterek the laminated Artush beds entirely disappeared under the gravel, which from its greater consistency assumed here the form of a rather tough, coarse conglomerate. In the bend of the river the latter have a thickness of fully 200 feet, and are eroded by lateral rivulets into remarkably regular Gothic pillars and turrets. It is rare to meet with a more perfect imitation of nature by human art. The general surface of the gravel deposits is comparatively low, from 400 to 500 feet above the level of the river, and much denuded and intersected by minor streams and old water-courses.

At a couple of miles north of Chungterek the Koktan range begins with rather abrupt limestone cliffs, rising to about 3,000 feet above the level of the Toyan. Nearly in the middle of it are situated the forts Murzaterek and Chakmák, some ten miles distant from each other. The southern portion of this range consists at its base of undulating layers of greenish or purplish shales, overlain by dark coloured, mostly black, limestone in thick and thin strata, the latter being generally earthy. The limestone occupies all the higher elevations, and, as is generally the case, greatly adds to the ruggedness of the mountains. About five miles north of Chungterek, I found in a thick bed of limestone an abundance of *Megalodus triqueter*, a large *Pinna*, a *Spiriferina* of the type of *S. Stracheyi*, blocks full of *Lithodendron* corals, and numerous sections of various small *Gastropods*. Thinner layers of the same limestone were full of fragments of *crinoid stems*, and of a branching *Ceriopora*, the rock itself bearing a strong resemblance to the typical St. Cassian Beds. In this place the shales, underlying the limestone, were partly interstratified with it, in layers of from 5 to 10 feet; and from this fact it seems to me probable that they also are of triassic age, representing a lower series of the same formation.

Proceeding in a north-westerly direction, the *Megalodus*-limestones are last seen near Murzaterek. From this place the greenish shales continue for a few miles further on, much disturbed and contorted; and at last disappear under a variety of dark coloured shales, slates, and sandstones, with occasional interstratified layers of black, earthy limestone. The strike of the beds is from east by north to west by south, and the dip either very high to north or vertical. At Chakmák the river has cut a very narrow passage through these almost vertical strata, which rise precipitously to about 3,000 feet, and to the south of the fort appear to be overlain by a lighter coloured rock. It is very difficult to say what the age of these slaty beds may be, as they seem entirely unfossiliferous, and we can at present only regard them as representing, in all probability, one of the palæozoic formations.

About five miles north-west of Chakmák a sensible decrease in the height of the range takes place, and with it a change in the geological formation. The palæozoic beds, although still crossing the valley in almost vertical strata, become very much contorted; while, unconformably on them, rest reddish and white sandstones and conglomerates, regularly bedded, and dipping to north-west with a steady slope of about 40 degrees. The rocks, though evidently belonging to a comparatively recent (kainozoic) epoch, appear to be much altered by heat, some layers having been changed into a coarse grit, in which the cement has almost entirely disappeared. I have not, however, observed any kind of organic remains in them. A little distance further on they several times alternate with successive, conformably bedded, doleritic trap. The rock is either hard and compact, being an intimate, rather fine grained mixture of felspar and augite in small thin crystals, or it decomposes into masses of various greenish and purplish hues, like some of the basic greenstones.

After leaving the junction of the Suyok and Toyan (or Chakmák) rivers, and turning northwards into the valley of the latter, the panorama is really magnificent. Shades of white, red, purple and black compete with each other in distinctness and brilliancy, until the whole series of formations appears in the distance capped by a dark bedded rock.

Although, judging from the greater frequency of basaltic boulders, we already knew that this rock must be found further north, we hardly realised the pleasant sight which awaited us on the march of the 4th January, after having left our camp at Kulja, or Bokum-bashi. The doleritic beds increased step by step in thickness, and after a few miles we passed through what appears to be the centre of an extensive volcanic eruption. Along the banks of the river columnar and massive basalt was noticed several times, with occasional small heaps of slags and scoriæ, among a few outcrops of very much altered and disturbed strata of red or white sandstone, thus adding to the remarkable contrast of the scene. In front of us, and to the right, stretched in a semicircle a regular old Somma; the almost perpendicular walls rising to about 1,500 feet above the river, and clearly exposing the stratification of the basaltic flows, which were successively dipping to north-east, east, and south-east. On our left, as well as in an almost due western direction, portions of a similar Somma were visible above the sedimentary rocks, all dipping in the opposite way from those ahead of us. The cone itself has in reality entirely disappeared by subsidence, and the cavity was filled with the rubbish of the neighbouring rocks.

Passing further north we crossed a comparatively low country, studded with small rounded hills and intercepted by short ridges with easy slopes; the average height was between 12,000 and 13,000 feet. This undulating high plateau proved to be one of the head-quarters of the *Kulja* (*Ovis Polii*), chiefly on account of the very rich grass vegetation which exists here. For this the character of the soil fully accounts. The entire ground was shown to consist of limestone gravel and pebbles of rather easily decomposing rocks, mixed with the ashes and detritus, evidently derived from the proximity of the volcanic eruption. Only rarely

was an isolated basaltic dyke seen, or the tertiary sandstone cropping out from under the more recent deposits.

Viewing the country from an elevated position near our camp at Turug-at-bela, the conglomerate and gravel beds, well clad with grass vegetation, were seen to stretch far away eastwards, and in a north-easterly direction across the Turug pass; while on the south they were bounded by a continuation of the somewhat higher basaltic hills. Towards the west I traced them for about seven miles, across a low pass at which a tributary of the Toyan rises in two branches; while on the other side two similar streams flow west by south to join the Suyok river. To the north the proximity of a rather precipitously rising range shut the rest of the world out of view. For this ridge the name Terek-tagh of Humboldt's map may be retained; its average height ranges between about 16,000 and 17,000 feet. In its western extension it runs almost due east-west, composed at base of a tough limestone conglomerate of younger tertiary origin, followed by white dolomitic limestone, and then by a succession of slaty and dark limestone rocks, the former occasionally showing distinct signs of metamorphism, and changing into schist. All the beds are nearly vertical or very highly inclined, dipping to north by west, the older apparently resting on the younger ones. North of Turug-at-bela the range makes a sudden bend in an almost northerly direction, and continues to the Chaderkul, where it forms the southern boundary of the lake-plateau. By this time the white dolomitic, and afterwards the slaty beds, had entirely disappeared, and with them the height has also diminished. A comparatively low and narrow branch of the range which we visited consists here entirely of dark limestone, which in single fragments is not distinguishable from the Trias limestone of the Koktan mountains, but here it does not contain any fossils. The ridge itself, after a short stretch in a north-east-by-north direction, gradually disappears under the much younger conglomeratic beds.

Across the Chaderkul plain the true Thian Shan range was visible, a regular forest of peaks seemingly of moderate and tolerably uniform elevation. The rocks all exhibited dark tints, but most of them, as well as the hills to the west of the Chaderkul, near the sources of the Arpa, were clad in snow. The lake itself was frozen, and the surrounding plain covered with a white sheet of saline efflorescence.

Brief sketch of the geological history of the hill ranges traversed.—In order that the preceding remarks may be more easily understood, I add a few words regarding the changes which appear to have taken place at the close of the kainozoic epoch within the southern offshoots of the Thian Shan which we visited.

Short as our sojourn in the mountains was, it proved to be very interesting and equally instructive. Humboldt's account of the volcanicity of the Thian Shan, chiefly taken from Chinese sources, receives great support; but we must not speculate further beyond confiding in the expectation that both meso- and kaino-zoic rocks will be found amply represented in it.

As far as our present researches in the physical aspect of the country extend, we may speak of three geologically different ranges: the *Terek range*, which is the northernmost, the *Koktan* in the middle, followed by the *Artush range*, below which begins the Kashgar plain. All three decrease in the same order in their absolute height, the last very much more so than the middle one. The first consists of old sedimentary rocks, the second of similar rocks in its southern parts, while younger tertiary and basaltic rocks occupy the northern portions, the third is entirely composed of young tertiary deposits. The general direction of all the ranges is from west to east, or nearly so; this direction evidently dating from the time when the whole of the Thian Shan chain was elevated. The undulating high plateau between the Terek and the Koktan is, near Turug-at-bela, about eight miles wide, the

distance between the two ranges diminishing westward, while in the opposite direction it must soon more than double. Judging from the arrangement of the pebbles, which, as already noticed, are half derived from limestone, the direction of the old drainage must have been from west to east, and must have formed the headwaters of the Aksai river, which on the maps is recorded as rising a short distance east of the Chaderkul. Similarly, the gravel valley between the Koktan and Artush ranges indicates a west to east drainage, and its width appears to have approximately averaged 20 miles. About three miles north of Chungterek a secondary old valley exists, also extending from west to east, and is diametrically cut across by the Toyan river. In this valley, which was formerly tributary to the one lying more southward, the gravel beds accumulated to a thickness of fully 100 feet. As the Artush range did not offer a sufficiently high barrier, masses of the gravel passed locally over it or through its gaps into the Kashgar plain, which itself at that time formed a third large broad valley.

Thus, at the close of the volcanic eruptions in the hills north of Chakmák, we find three river systems all flowing eastward, and made more or less independent of each other by mountain ranges, about which it would, however, not be fair to theorizè (in the present state of our knowledge) on the causes of their assumed relative position. It must have been at that time that the pebbles of protogine were brought down from some portion of the hills lying to the west; and it would be interesting to ascertain whether or not this rock is anywhere in that direction to be met with *in situ*. When the turbulent times of Vulcan's reign became exhausted and tranquillity was restored, the whole country south of the axis of the Thian Shan must have greatly subsided, and the wider the valleys have been, the more effectively was the extent of subsidence felt. To support this idea by an observation, I may notice that north of Chungterek, at the base of the Koktan range, the Artush beds have entirely disappeared in the depth, and the gravel beds overlaying them dip partially under the Trias limestone, a state of things which cannot be explained by denudation, but only by subsidence and consequent overturning of the older beds above the younger ones. A similar state of things is to be observed on the Terek range, where the young tertiary limestone conglomerate is in some places of contact overlain by the much older dolomite. Now, if the broad valley of the Kashgar plain sank first, and gradually lowest, as it in all probability did, we find a more ready explanation of the large quantities of loose gravel pouring into it and accumulating at the base of the Artush range.

The sinking in of the volcanic centre north-west of Chakmák first appears to have drained off the former head of the Aksai river, making it the head of the Toyan instead; and to the north of the Terek ridge it was most probably the cause of the origin of the Chaderkul. The subsidence of the country followed in the south, making it possible for the united Suyok and Toyan rivers to force their passage right across the Koktan range, strengthen the Artush river, cut with facility through the Artush range, and join the Kashgar-daria. While thus indicating the course of the comparatively recent geological history of the ground, it must be, however, kept in mind, that this change in the system of drainage had no essential effect upon the direction of the hill ranges. This, dating from much older times, was mainly an east-westerly one, following the strike of the rocks which compose the whole mountain system.

KASHGAR,
16th January 1874.

NOTE.—Since the foregoing paper was in type, the calamitous news of Dr. Stoliczka's death has been received. This opportunity is therefore taken of publishing a few last geological notes communicated in a private letter. The following is from a letter dated Kila Panj, Wakhan, 14th April 1874:—

"We crossed from Yangihissar to Sirikul in ten days; and after two days' halt at that place, crossed Pamir Khurd in twelve days. The last few marches on this side were about the worst we had. The road is very bad, and the daily snow-storms so heavy, that on one day we were not able to make more than five miles. Wakhan itself is a miserably poor country; and it is a question whether we shall be able to get enough supplies to take us back, if we do not get something sent up from Fyzabad. Our ponies will require at least twelve days to recover from the fatigue they had on the little Pamir. Whether by that time the road by Pamir Kalan will be open is very questionable.

"I ought to tell you something of the geology, but it is in very few words. There are no younger rocks the whole way than trias limestone. The Pamir Khurd proper is all gneiss and metamorphic schist. Do not imagine that the 'roof of the world' is an elevated plain; nay, it is a mere valley, well supplied with gneiss and boortsee, and from two to three miles in width. From the hills to the south, glaciers come down almost into the valley; while the hills on both sides were deeply clad in snow; so much so, that for several miles not even a few square feet of bare rock was visible. If we go back by the Pamir, I shall try to make a halt of two days before reaching Sirikul, and examine the triassic limestone. The old slates give no hope of yielding any trilobites."—EDITOR.

ON THE FORMER EXTENSION OF GLACIERS WITHIN THE KANGRA DISTRICT, *by* W. THEOBALD, *Geological Survey of India.*

Preliminary remarks.

The subject of the former extension of glaciers along the southern slopes of the Himalayan chain to far greater distances than they now reach to, might at first seem of necessity to involve, for the due treatment of so comprehensive a question, the examination of a far wider area than I am about to review in my present remarks, and this to a certain extent is true, for the phenomena in question undoubtedly form but a portion of a very grand and widely spread display of glacial conditions extended over an area which, from the insufficiency of our data, it were at present premature even to endeavour in the most general way to indicate by limits; nevertheless, as it is hardly possible for the more enduring results of long continued glacial conditions to be better studied or more characteristicly displayed than in the Kángra district, and as the subject, moreover, is one which has been rather neglected by previous writers, I conceive that a few remarks thereon, even confining myself to the limited area indicated, will not be altogether without interest and value as a basis whence future observations may be extended both in an eastern and western direction.

Moraines, the most striking no less than the most enduring of the products of glaciation, form so conspicuous a feature of the surface of so large a portion of the Kángra district, that the attention of the least observant traveller is rivetted by them, and I had hardly set foot in the district before I was questioned as to the origin of those trains of loose stones so common near the hills, and whose general aspect was so different from the ordinary accumulations of débris usually swept down by streams in such situations, and the magnitude of so many of the boulders in question rendering it obviously difficult to refer their transport to the agency of hill streams and suggesting rather the intervention of some mysterious or cataclysmal debâcle.

Medlicott in Memoirs, Geological Survey.

Mr. H. B. Medlicott, in his paper on Himalayan Geology dated January 1864 in Vol. III of the Memoirs of the Geological Survey of India, page 155, was the first to draw attention to the presence of 'erratic' blocks along the "base of the Dháoladhár" and to record their occurrence in this region "at so inconsiderable an elevation as 3,000 feet," but no attempt is made to define the precise limits within which these erratics occur, or to map their course. In fixing their lowest limit too at 3,000 feet, Mr. Medlicott has somewhat erred on what may be termed the safe side, since the fort of Kángra, which is the midst of them, is no more than 2,419 feet above the sea, while 2,000 feet may in round numbers be taken as the mean elevation of the isothermal line, coincident with the limits of the terminal moraines. The statement, too, that erratics first appear on the "east about Haurbágh" is likely to convey an erroneous impression as I shall hereafter show, since though undoubtedly there is a very sudden development, as it were, of these 'erratics' from Haurbágh westwards, yet their absence eastwards from this point, is due to denudational causes, and not to a sudden or local development of glacial phenomena continued along the flanks of the Dháoladhár range, west from Haurbágh merely, but of this more in the sequel.

Dr. Verchére.
Notice of erratics and floating-ice.

Dr. Verchère, in his account of the Geology of Kashmir, the Western Himalaya, and Afghan Mountains, in the Journal of the Asiatic Society of Bengal for 1867, Vol. XXXVI, Part II, page 113, describes erratic blocks north of the Salt Range, in Latitude 33°N. and refers them to the agency of floating-ice; but there does not seem anything in his description incompatible with the idea of these blocks being the disintegrated remnants of old moraines, rather than due to the transporting powers of floating-ice; and it is, I think, rather more probable than otherwise, that they will prove to be strictly connected with the erratics of Kángra, and of cotemporary origin, during the glacial period to which my present observations refer. Speculation on this point is, however, premature, and must wait the result of observations over the intermediate area, which have yet to be recorded.

Constitution of moraines.

The task of tracing out the course of the moraines which descending from the Dháoladhár range pushed boldly across the Kángra district, is rendered unusually easy from the great contrast which exists between the rock of which the great majority of erratic and moraine blocks consist and the tertiary clays and sandstones whereon they lie. Near the boundary of the tertiary groups, the erratic blocks almost wholly consist of an easily recognised granitoidal gneiss, usually highly porphyritic, forming the central mass of the Dháoladhár range, and which rock, only towards the eastern extremity of the district, assumes a distinctly schistose or fissile habit, which proclaims its relation to the gneissose or metamorphic group of rocks, rather than to an intrusive rock or granite proper. After traversing, however, for some distance the area occupied by tertiary rocks, the moraines are found to consist, in addition to the gneiss of the Dháoladhár, of an ever increasing admixture of well rounded and water-worn boulders, from 4 inches up to 9 feet or more in girth, of the harder schistose and silicious rocks, derived from the coarse boulder conglomerates constituting the uppermost beds of the Náhun, or miocene tertiary, group through which the old glaciers ploughed their way. In proportion, too, with the decrease in number of the Dháoladhár erratics, compared with the other materials of the moraine, a diminution in size may be remarked, till eventually only an occasional small boulder, to be detected only here and there if carefully looked for, remains of the Dháoladhár gneiss, to indicate by its tell-tale presence the former extension of the glacier on which it had travelled so far; and it can therefore be readily understood how, in some cases, the actual extent of a glacier may have been greater than that assigned to it, from the difficulty, in the absence of the familiar Dháoladhár rock, of discriminating between materials properly belonging to an old moraine and the precisely similar materials

where the moraine has either ceased or become wasted and enveloped in deposits due to atmospheric and fluvial agency as opposed to glacial, the more so as the moraines themselves have, since the period of their final arrest, been everywhere subjected to the energetic operation of the former forces. The actual limits, however, within which it is doubtful if glaciers formerly extended or not, from the disintegration and rounding off by subsequent atmospheric action of their terminal moraines, are extremely narrow; but the vast power of denudation in particular places, and under favorable conditions of surface, and the ability of the existing rivers to remove every trace of former moraines, is in many places well illustrated in the area under review.

Power of denudation to obliterate moraines regulated by conditions of surface.

From general considerations there can be little or no doubt, that the valley of the Biás afforded passage to a noble glacier, to a point at least as low down as Nadáon, which would give a course of 120 miles in length from the snow-fields at the sources of the river; but the present main channel of the river has since that period been so deeply and sharply excavated that not a trace (or such at least as a cursory examination would enable one to detect) exists of a moraine, such as we know must have resulted from and marked the course of so extensive a glacier. At Sujánpúr the moraine of the Sujánpúr glacier is seen pushed right across the present channel of the Biás, at a much higher level than that of the present stream, which has made a clean and deep cut through it; yet, though the erratic blocks scattered round the Traveller's Bungalow at Sujánpur, and all over the truncated end of the moraine on the opposite side of the river, are of a large size, not a trace of one can be seen in the river bed beneath. This fact conclusively shows the power of the existing rivers (where from their narrowed channel, as at Sujánpúr, their effective force is largely increased) to utterly remove all traces of such deposits as these old moraines even where they contain massive boulders of 12 feet in girth and upwards; or what is rather more likely than any actual transport of such blocks is, that when once fairly sucked into the waterway, they are pounded to pieces by the incessant impact against them of the hard silicious boulders driven forcibly against them during floods. No one who has listened to the ceaseless thunder and muffled rattle of a swollen Himalayan stream can doubt the full power of such an agent to effect in time the above result.

Sujánpúr (glacier). Moraine breached by the Biás.

Again, between Mandi and the bridge over the Biás, below that town, undoubted traces are met with of the old trunk moraine of the Biás valley, where the present valley is rather open; but just above and for a long way below the bridge, the river gorge is swept perfectly clean, as with a besom, of all traces of a moraine, such as may be noticed a little higher up; and this would seem to be generally the case where the valley narrows, or is unusually precipitous, either in the main channel of the Biás, or in the channels of its tributaries, the power of moraines to withstand the erosive action of rain and rivers depending far more on the physical character of the gorges they occupy, and the slopes whereon they repose, than on either their bulk and dimensions or the magnitude and character of the materials of which they are composed.

Trunk glacier of Biás.

The Ul (Ool) river which enters the Biás above Mandi takes its rise in the continuation of that line of snowy peaks whence the glaciers of the Kángra district descended, and no one who has examined the district, or has a tolerable map to consult, can entertain the shadow of a doubt that an enormous glacier must have once traversed the valley of the Ul, debouching into the Biás valley and uniting with the great trunk glacier of that river above Mandi. But no trace of any moraine could be detected in that portion of the Ul valley near Jatingri

Valley of the Ul.

Absence on it of moraines, due to its physical configuration.

examined by me, and a perfectly adequate explanation of this circumstance is, I think afforded by the very steep character of the hill sides bounding the valley. The Ul valley is not only very straight, but remarkably steep, the sides in many places forming an angle of not less than 60,° so that any one who will reflect what sort of a slope in nature an angle of 60° represents, will easily understand how impossible it would be for such incoherent materials, as moraines are made of, to effect a lodgment in such a situation, and resist for ages the combined effects of floods in summer and avalanches or snow slips in spring, to sweep them *en masse* into the yawning gulph below.

Map of the district and enumeration of glaciers.

A reference to the accompanying map will give a clearer idea of the general course, arrangement and relations to each other of the glaciers which formerly traversed the Kángra district, than any mere verbal description; but neither the scale of the map nor the time I was enabled to devote to the subject suffice for any attempt at details as regards the various subordinate features and minor surface changes referable to the glacial period in question, though the sketch embraces all the essential points of the case.

Between Mandi on the east and Nurpúr on the west (being the area to which my remarks are mainly confined) seven principal glaciers descended into the valley of the Biás, which was then of course filled by a superb trunk glacier to which the above served as lateral feeders, and which taken in order from east to west may be thus described.

1.—The Dailu Glacier.

The Dailu glacier.

The most easterly feeders of this glacier passed down through the village and thannah of Haurbágh in Mandi, and after being joined by several equally large or larger glaciers from either side of the village of Dailu, the united glacier descended the narrow valley of the Rána river, which joins the Biás ten and half miles below Mandi. The most westerly feeder of this glacier was formed by the bifurcation of a huge glacier, which descending nearly opposite the village of Aiju, there split into two streams, one of which descended the Rána valley, whilst the other assumed an opposite course, and formed the most easterly feeder of the next glacier.

2.—The Baijnáth Glacier.

The Baijnáth glacier.

This glacier was formed by the union of several large glaciers, which united below Baijnáth and pursued a course down the valley of the Bimm river, which joins the Biás nearly midway between the mouth of the Rána above and the large town of Sujánpúr below. The most easterly branch of this glacier has been noticed above, as coming from near the village of Aiju, whilst the most westerly branch was similarly formed by the bifurcation of a vast glacier, which passing down a little to the east of the village of Banuri (Bunooree) was split into two streams against the cuneiform mass of hills some three miles south of that village.

3.—The Banuri (Bunooree) Glacier.

The Banuri glacier.

This glacier is the smallest, as far as the area covered by it, of any under notice, and might be regarded almost as a satellite of the next, with which it was probably intimately connected, but as some of its moraines reach the Biás by a separate course it is enumerated with the rest. It consisted mainly of the westerly feeders of the glacier above described as bifurcating south of Banuri, with some obscurely defined contributories, still more to the west, and joined the Biás some few miles above Sujánpúr.

4.—THE SUJÁNPÚR GLACIER.

The Sujánpúr glacier.

This very large glacier was composed of several parallel and inosculating streams, all running with a comparatively straight course past Burwárneh to the Biás at Sujánpúr, the main stream having evidently descended along the course of the Negál river.

5.—THE HARIPÚR GLACIER.

The Haripúr glacier.

This was the largest and most interesting glacier under notice. The most easterly feeders of it passed close under Dhár bungalow past Puthiár, and thence with a grand curve south of Nagroteh; whilst the most westerly feeders descended close to Bághsu cantonments. Between these limits a number of glaciers descended from the lofty Dháoladhár range, pierced the outer range of schistose rocks, and coalescing below Kángra into one mighty stream ploughed their resistless way through the tortuous gorge of the Ban Ganga, past Haripúr, and through the village of Godeir (below which large erratics are scarce) as far as the village of Ghuriál (Ghooryal) or perhaps even farther.

6.—THE GUJ GLACIER.

The Guj glacier.

This glacier might be appropriately named after the village of Nagroteh, near which it debouches into the plains, but as there is a better known village of that name, mentioned above, east of Kángra, it will obviate confusion if the name of the river down which it passed is substituted. The most easterly feeders of this glacier descended a little west of Bághsu, the most westerly ones, a little west of Rihlu (Rihloo).

7.—THE JAWÁLI (JUWALEE) GLACIER.

The Jawáli glacier.

This glacier, the most westerly one in the Kángra district, was composed of two main branches, one from the east, flowing under Tiloknáth, whilst the other passed down close under Kotleh, below which place the two united, flowing from nearly opposite directions, and together passed down the gorge of the Darh river, debouching into the plains at Jawáli. Below Jawáli the moraine of this glacier, mainly, perhaps, through the action of subsequent atmospheric forces, spreads out into a fan-shaped talus (and the same is more or less observable in the case of the Guj glacier also), so that its precise termination is not clearly marked, but it not improbably extended to the Biás either independently or after uniting with the last.

Existing glaciers of this region.

In speaking of the glaciers enumerated above I have used the past tense, as I am uncertain if at the present day even so much as a permanent remnant remains of some of them; though to the eastward of the region they originate in, towards the head of the Ul valley, snow-fields and glaciers are represented on the map. Whether or not shrunken remnants of any of them still remain pent within the deeper vallies among the peaks of the Dháoladhár range, is of little moment, since the precise course pursued by them is no less plainly marked by the Cyclopean trains of boulders they have left behind them, than if they were still present to our eyes on their original proportions.

Moraines in Kángra.

The moraines within the Kángra district present everywhere such similar features that a description of one of them will *mutatis mutandis* stand for all the rest, the differences between them being confined to their relative size, and the secondary characters impressed on them by atmospheric action, and the extent to which they have been cut into and abraded by existing streams. Descend-

ing from the central peaks of the Dháoladhár range, in the form of sinuous streams of boulders, rugged, angular, and massive, many of which attain over 50 feet in their greatest diameter, they traverse by narrow gorges the range of hills composed of schistose rocks, intervening between the Dháoladhár range and the plains of the Kángra district, on reaching which they expand, inosculating and coalescing in the open ground to such an extent as to cover the greater portion not occupied and defended against invasion by hills. In fact so complete was the union of these glaciers that the whole of the area shown in the map to have been traversed by them must have presented the appearance of one huge ice-field, if we can rely on the evidence of the perfect mantle of moraine material which now covers the ground.

Former appearance of Kángra district.

The size of some of the gneiss blocks which have travelled well out into the plains is surprising, till the mind fully realises the quasi-omnipotent power of the agency involved in their transport. Near Busnur south of Rihlu, I measured one block embedded in a field by the roadside, 125 feet in girth, and in this and other cases the present dimensions are probably much under the original size of the block, from the desquamation of the surface under the action of frost, sun, and rain, and in some situations by the friction of stones swept against them by streams. Again, between Bághsu and Dárh, four blocks in the immediate neighbourhood of the road measured in girth, respectively, 100, 125, 134, and 140 feet. Blocks of this size occur, of course, but seldom, but those from 70 to 100 feet somewhat more commonly, whilst blocks approaching 50 feet in girth are too numerous to reckon. So great is the abundance of the rocky fragments brought down by these glaciers, that the entire country just outside the narrow schistose range, which skirts the district to the north, is so covered with them as to leave no other rock visible; and but for the fact that none of these blocks can be seen *in situ*, and for the section occasionally revealed in a deeply cut river bed, the casual traveller might very naturally consider the whole area he was traversing to be granite or gneiss.

Size of erratics.

The process by which this condition has been brought about is a very simple one, but at the same time bears striking proof of the magnitude of the forces at work, and the duration of the period during which they were displayed. On quitting the narrow gorges in the hills wherein they had hitherto remained forcibly pent up between rocky walls, the glaciers at once expanded, partly through the natural tendency of a piled up mass, possessing the known plastic character of glacier ice, to spread out on a level surface, under the simple operation of gravity, and partly to the lateral displacement which later glacial accessions descending such gorges would receive from the accumulated moraines of earlier years, heaped up in their direct path, either during periodical meltings or during the secular retrocession, probably not a continuously uniform process, of the isothermal line of the terminal moraines of the whole group of glaciers in question. Exception will doubtless be taken by some to the idea of expansion through plasticity having had any appreciable influence in producing any lateral diversion of the moraine when they enter the plains, and I am prepared to admit the subordinate operation of this cause to the second one I have mentioned, but that it was a *vera causa* to a certain extent will, I think, be admitted, if due weight is given to the probable dimensions vertically of the glaciers in question. If, as has been conclusively established, a *shallow* glacier can quadruple its thickness when compressed between narrow limits, it cannot be theoretically denied the power of reassuming a shallower, that is, a more *expanded* form, when, on issuing from the hills, it becomes relieved from all pressure having a tendency to counteract the ordinary effects of gravity on a plastic body, heavily weighted by the pressure of the enormous moraines supported by it, which can hardly be so insignificant as with time to produce no appreciable result. Thirty or 40 feet is no uncommon thickness for one of these Kángra moraines, and I greatly doubt if in some cases a hundred feet

Fan-shaped expansion of glaciers on quitting the hills.

would not be an under estimate. If then we make allowance for the intermingled ice and snow, which must have cemented this prodigious mass together, we shall not greatly err if we calculate the pressure it must have exerted on the glacier, whereon it rested as equal to a stratum of solid granite of one-half that thickness, a force amply sufficient, when applied to such a thick stratum of plastic* glacier ice, as we must suppose to have been associated with such giant moraines, to have produced a very sensible lateral expansion of the ice river, initiative, if no more, of that expansion or lateral deviation, a tendency to which all the moraines, more or less, at present display on debouching from the hills.

Deviation of glaciers.

That later glaciers have thrust past earlier ones, and intersected their moraines, seems scarcely to admit of a doubt, thereby producing an irregularity and confusion in the arrangment of the erratics and materials of moraines spread over the country, at first suggestive of the less regular or sporadic agency of floating-ice rather than of glaciers, whose frequent inosculation has been the real cause of the irregularity in the network of resulting moraines.

Kángra to Bághsu.

Along the course of the road from Kángra to Bághsu numerous illustrations of the conditions sketched above present themselves. Long lines of moraines are seen to stop abruptly and sink out of sight beneath the soil; sometimes indicative of the arrest, either temporary or final, of the parent glacier, at others of the disruption and truncation of a moraine by a glacier of later date pursuing a nearly coincident course. Near Bogli, after passing the temple and tank of Gangabarabi, the road skirts a low ridge, with a well-marked moraine on the right—a long string of erratics, whose course is sharply defined; but on turning the end of the ridge, and looking towards the village of Ich-hi, the country is seen freely overspread with blocks in which no regular order can be made out.

Floating-ice—no conclusive evidence of.

The suggestion of Mr. Medlicott, as to the possible intervention of the agency of floating-ice, in distributing erratics in Kángra, here occurred to me, but I was eventually led to reject the idea, from the fact that, as far as my observation goes, these erratics never ascend beyond a certain relative height, which being no greater than that within which the traces of glaciers are found, goes far to disprove the intervention of any other agency for the distribution of the blocks in question. It is of course obvious that floating-ice and glaciers could not have cotemporaneously occurred over the same area, and the fact that no erratic blocks are known in Kángra, beyond the general limits attained by glaciers as fixed by their continuous moraines, is hence almost conclusive disproof of the agency of floating-ice within the district. The erratic blocks are so marked in character that they could scarcely escape detection, if they occurred beyond the limits above assigned to them, and this, for a negative argument, must be allowed unusual weight. If then the above conclusion is correct, the more perfect and lineal moraines are the youngest, and (trivial atmospheric denudation apart) exhibit the precise appearance they did on the waning of the glacial conditions in which they originated, whilst the more scattered and dissociated blocks must be regarded as the fragmentary remnants of more ancient moraines, whose continuity has been long since destroyed by surface changes wrought by the altered course and direction of glaciers of a later period.

Disproof of its former existence in Kángra.

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* Prof. Tyndall very justly combats the idea of ice being regarded as a 'viscous' body, properly so-called, and would seem to touch the root of the matter, by limiting this so-called viscous quality of ice to a capacity of yielding to *pressure*, not *tension*. With this cardinal fact established, it is unfortunate that the term 'plastic' was not always used in place of 'viscous,' as the essential idea of adhesiveness involved in the word 'viscid' or 'viscous,' in addition to the mere property of 'plasticity,' was not really necessary to the theories of hose who used the term.

All the Kángra moraines have a very arched or 'hog-backed' outline, and are always separated by a more or less strongly marked valley or ravine from the hills round which they pass. In the case of the larger moraines, the resulting effect on the landscape is rather curious: hills viewed across one of these moraines have a peculiar sunken or 'hull-down' appearance, from the crest of the moraine intercepting all view of their base, as the marine horizon does of a vessel's hull at a certain distance, and trees and villages situated on the opposite slope of one of these moraines from the observer are from the extreme curvature of its surface similarly concealed from view.

Another feature of the surface, occasionally very prominently displayed, is the rapid slope of a moraine across the valley wherein it debouches. This is well seen in the moraine west of Dailu bungalow, in the rapid slope of that portion which passes from Aiju down the course of the Rána river. The river running past the village of Dailu brings down no erratics above that village, but Dailu itself stands on the verge of an easterly branch of the same glacier which joins it lower down.

Physical features in Kángra resulting from glacial conditions.

I will now describe certain physical peculiarities of surface in the Kángra district directly connected with the glacial conditions which formerly prevailed there.

The Kángra district may be ideally divided into three vertical areas or zones.

1st, preglacial area.

Firstly, a preglacial area embracing the whole country which contributed, from peak to plain, towards the genesis and development of the glaciers under consideration; speaking roughly and without any measured data to check the estimate, the above zone or area embraces all ground higher than from 250 to 300 feet above the mean level of the present streams.

2nd, glacial area, proper.

Secondly, a glacial area, proper, embracing the entire area either occupied or excavated by the glaciers, which may be approximately fixed as commencing at the bottom of the above division and terminating below at a level of about 150 feet more or less above the mean level of the present streams.

3rd, postglacial area.

Thirdly, a postglacial area embracing the whole of the ground below the basal limit of the last division, and the rësult of aërial denudation subsequent to the cessation of glacial conditions.

The first division calls for little remark save that it is the area within which we should most naturally expect to meet with erratics, deposited from floating-ice anteriorly to the formation of the moraines of the lower ground, had any such agency been in operation; but I am unacquainted with any such, and therefore, no less than from the physical difficulties such a supposition would involve, have rejected it for the simpler one of glaciers, whose former prodigious development is so stamped on the country. By floating-ice, I of course understand ice floating at or near the sea level, since the assumption of floating-ice in some elevated inland sea, of sufficient height to bring its waters within reach, or nearly so, of the ordinary glacial isothermal of its latitude, is perfectly unwarranted by evidence, certainly at least in the Kángra district; the only fine clayey deposit, the result of a tranquil mode of deposition, which could possibly be referred to such conditions, being a red clay of clearly postglacial age, which in some parts attains considerable development, and which may be referred to a postglacial period of lacustrine deposition coincident with a general subsidence of the whole Himalayan region and the gradual approximation of the general climate to that which at present obtains. This red clay covered at one time enormous areas in Kángra, and may not improbably mark a period of true lake formation, when along the southern slopes of the Himalaya lakes existed more extensively than existing indications would lead

us to suppose; but denudation has to a large extent removed all traces of this finer deposit, though still to be found here and there if sought for, as, for example, south of Nadáon and between Jawáli and Nurpúr.

The second division is emphatically the area of glacial display, and to it are restricted all the moraines and erratics, which are approximately in the position where they became fixed on the waning of glacial conditions, and nowhere can the relations of this to the other divisions be better seen than near the town of Kángra.

Kángra.

Approaching Kángra by the Jullunder road after passing the village of Dowlutpúr, the road commences the ascent of a steep ridge of hills at first composed of pebbly sandstones with a little red shale, which soon give place to thick beds of very coarse conglomerate, which throughout Kángra constitute the highest sub-division of the Nahun group of tertiaries, of presumedly miocene age. The crest of the ridge is pierced by a tunnel, shortly after passing through which, and commencing the descent towards Kángra, a fine view is obtained of the celebrated fort of that name, perched on a cliff, overhanging the boiling river below, the cliff as well as some scarped heights beyond and above the fort consisting of the same coarse boulder conglomerates as those constituting the ridge over which the road is carried. When about half way down the road or rather more, a few large boulders of 'Dháoladhár' gneiss may be detected lying about, or wedged into clefts and gullies worn by surface water in the coarse conglomerate, and into which situation they have rolled from above, as these gneiss boulders in question are not weathered out of the conglomerate, but are the familiar erratics from the Dháoladhár moraines. Continuing to descend, these boulders increase in number, till the stream (a branch of the Ban Ganga) is reached, when its bed is seen to be filled, and I may almost say, blocked, with enormous masses of the Dháoladhár gneiss, contrasting curiously in the eyes of a geologist with the beds of boulder conglomerates wherein the river gorge is excavated and wherein they are wholly wanting.

Contrast between gneiss boulders in stream and banks of conglomerate.

Immense boulder from the Nahun conglomerates.

I should not omit to notice in this portion of the road opposite Kángra, the occurrence on the road side of a large boulder of red quartzitic sandstone, of nearly 15 feet in girth. This boulder is undoubtedly an erratic, but derived from the coarsest upper beds of the conglomerates so largely here developed, but which have nearly everywhere suffered so from denudation, that little, save huge boulders strewed about, indicates their former presence. This particular boulder is interesting from being the largest from these beds I have anywhere measured, and for a true water-worn * and rolled boulder it may be considered immense, the second to it in size being, however, close on 12 feet.

Level of the base of the glaciers about Kángra.

Where the road crosses the stream the valley is narrow, but higher up it opens out more, and is seen terraced on different heights, most of such ground being under cultivation. Just below the fort stands the soldiers' church, and it would seem to mark nearly the lowest limit or level of glacial erosion proper, that is, the level of the bed of the old glaciers, or, perhaps, a trifle below it. The post office, on a slightly higher level, seems well within the vertical zone or valley of glacier erosion, and the mean between these two points may be taken as the approximate mean level hereabout of the base of the old glaciers. Passing on to the dâk bungalow scattered erratics are seen on the steep sides of the valley, becoming scarcer as we ascend

* This term of course applies to its original formation as a water-worn boulder in a coarse boulder conglomerate, not to its last vehicle of transport which I take to be 'glacial.'

to the immediate vicinity of the bungalow. Still, however, the dâk bungalow, or rather perhaps the still higher Mission church, may be regarded as marking the highest level of glacier action; and to the action at a very early epoch of a glacier descending the course of what is now a deep valley beneath the dâk bungalow to the north, I am inclined to refer the flat truncated outline of a hill which confronts the dâk bungalow at a nearly similar elevation in that direction.

The difficulty of always satisfactorily determining the upper limits to which glaciers have reached arises from the paucity of moraine débris, and erratics in such situations, especially where the ground has been steeply carved out as near Kángra; whilst the precise lower limits of glacier erosion are not uncommonly obscured by the subsidence in mass of the moraine, *pari passu* with the subsequent fluviatile and non-glacier erosion which has latterly supervened.

The third division, of postglacier erosion, calls for brief remark. Its area is freely covered by moraine débris and erratics, which, in the case of the large fragments, have simply subsided *pari passu* with that denudation which has removed the base whereon they rested. A very neat illustration of this process is seen in the bed of the stream beneath the road near the dâk bungalow. The river takes a sharp bend round a sort of promontory sharply cut out of the old plateau in which the present river has excavated its bed, and above which the old glaciers passed at a higher level. The true character of the linear trains of boulders here seen, and the fact that they are moraines subsided *in situ*, are clearly shown. These lines of boulders evidently stretched down, quite irrespective of the present river, over ground, now represented merely by the narrow spit left by the river. On this spit the boulders are seen to rest, and if it might be possible for the stream to have imparted the linear arrangement to these trains of huge boulders, it is obviously beyond the power of water to have washed them up against the face of the spit in the manner in which they occur.

Dr. Falconer on the absence of lakes south of the Himalayas.

A few words may not here be out of place touching the views held by Dr. Falconer on the causes which have acted towards the conservation of lakes in the Alps, and the probable reason of the non-existence of any lakes of similar magnitude along the vastly more colossal Himalayan range, where their presence might not unnaturally be looked for on a scale of even greater magnitude than in the neighbourhood of the Alps; since the glacial phenomena previously described by me go far to invalidate the conclusions which Dr. Falconer, in ignorance of the former existence of the phenomena in question, was led to draw. Dr. Falconer, writing on this subject, regards the Alpine lakes (Falc. Palæont. Memoirs, Vol. II, page 651) as great fissures with rivers running into them, which originated in the process of elevation of the whole chain. Precisely similar results in his opinion followed the elevation of the Himalayas, but in the Alps a glacial period supervened, which filling these 'fissures' or lake basins with ice, prevented their being choked up with detritus, as would have happened under milder climatal conditions. For India, on the other hand, "these lake basins were gradually silted up by enormous boulders and alluvium of every kind," since in these "tropical regions the ice never descended from the highest summits down into the plains."

Views of Dr. Falconer untenable.

Now, the condition of the Kángra district clearly renders the above view of Dr. Falconer untenable, since it is abundantly clear that glaciers descended well into that outer region, wherein we might expect lakes to occur, and it is clear that no material difference existed between the Himalayas and the Alps, *quoad* climate and the former prevalence of glacial conditions over both areas. Whether at any period lakes existed within the Himalayan area, comparable with those bordering the Alps, may be allowed to remain an open question, which, I am not disinclined

to think, will hereafter be answered affirmatively; but whether they once existed or no, we have in the excessive erosion of the river channels traversing the drainage basins, wherein any such lakes must have stood, a cause fully adequate to account for their subsequent disappearance. In the open ground of the Kángra district I have estimated the amount of erosion of the river beds since the termination of the glacial period as upwards of 100 feet, and there seems to me no fixed limit which we are called on to assign in the case of those larger rivers which descend from the main Himalayan chain, so that even had large lakes occupied positions along the main river vallies subsequent to the glacial period in question, we can still understand, from what is seen in the Kángra district, how such lakes may have emptied by the ordinary operation of those forces which are now and ever have been perpetually at work deepening every Himalayan gorge. I content myself, however, with throwing out the hint, as the subject is too large a one to be discussed in a paper like the present.

Period of glacial conditions in Kángra.

It remains only to add a few words on the period during which glacial conditions prevailed in Kángra, and this is capable of being fixed with tolerable exactness with regard to the tertiary deposits of the region.

'Nahun group.'

The great bulk of the tertiary deposits of the Kángra district belongs to the 'Nahun' division of Mr. Medlicott, approximating in age to the miocene of European geology. This group contains in addition to numerous Pachyderms and Ruminants (a correct and discriminative list of which is a most urgent desideratum), the remarkable Chelonian *Colossochelys Atlas*, Fal.. This group of an enormous, but unascertained thickness, not less certainly than 10,000 feet, was tilted up and involved in the great disturbance its beds display, and moulded to the main orographical features of the district prior to the development of the glacial conditions in question.

Sivalik group.

The Nahun group is followed by a series of deposits of very inferior thickness, but not less rich in remains of a varied fauna. Within the Kángra district no direct evidence exists, from contact, of the relative age of the glacier deposits and the Sivalik group; but the evidence afforded by the fauna of that group is wholly in favor of its being postglacial, and of the fauna being associated with conditions of climate analogous to those now existing. Without entering into greater detail, it is sufficient to mention in support of this view the occurrence of two living crocodiles in the Sivalik beds, and several species of land and fresh-water shells still living, and the same association of extinct types with the precursors of numerous species of living mammalia, as is seen in the pliocene deposits of the Narbada valley.

Glacial phenomena east of Kángra.

With regard to the occurrence of glacial phenomena along the Sub-Himalayan region east of the Kángra district, I think that future observations specially directed to the subject will reveal an unexpected amount of evidence, which, if not so obvious, will be found no less conclusive than that displayed in Kángra. The scope of my own observations only permits my saying that remnants of moraines occur in the Sutlej valley as low down as Bilaspúr, and erratic blocks, not now directly connected with any moraine, but probably transported to their present position by a prodigious trunk glacier which descended the Sutlej valley without much reference to its present configuration, as low down as the mouth of the Gumber river and probably lower. The blocks I refer to a moraine at Bilaspúr consist of the harsh Krol limestone forming the ridge which near that town is cleft by the valley or gorge of the Ullay river, down which a glacier passed into the trough of the Sutlej. Anything, however, like a connected moraine of this Sutlej glacier no longer remains; but to its disintegration and removal is no doubt largely due the enormous sheets of recent con-

Moraines at Bilaspúr.

Erratics in the Gumber.

glomerate, which literally choke the Sutlej valley, and which may be well seen, among other spots, at Dihur (at the ferry on the Mandi and Bilâspur road), at Bilâspur, and at Bubhor, where the Sutlej debouches into the Una dún.

Section of the Sutlej above Dihur.

Approaching the Sutlej from the direction of Mandi, when a little better than a mile from the ferry, the whole of the high ground behind the village of Kángra is found sheeted over with beds of sandy gravel evidently the upper beds of a thick deposit of either fluviatile or lacustrine origin, mantling round the hills of harsh Krol limestone bounding the valley, which to a great extent it must have originally filled. On descending towards the river these sandy beds give place to coarse gravels, which still lower down pass into the coarsest boulder shingle, mainly composed of a heterogeneous mixture of Himalayan rocks, among which the Krol limestone of the neighbouring hills is a prominent ingredient. Among the rest, scattered boulders of the porphyritic gniess of the Dháoladhár are seen, from their size of unquestionable glacier origin, and these may be traced as low as Dihur, of various dimensions up to 8 or 10 feet in girth, associated with numbers of boulders of nearly the same size of the hardest schistose and trappean rocks, from the region of the inner hills, and all at one time probably transported to the vicinity by glacier agency.

Erratics at Bilâspur.

At Bilâspur in the bed of the river beneath the Rajah's Garden, I remarked erratic blocks of hard schistose rocks from 12 to 15 feet in girth, but to what precise distance down below the Gumber mouth these can be traced I cannot say.

Reflections.

But what a vision of the past is not here raised by these simple boulders lying neglected in the river bank or used for the ignoble purpose of cleansing the clothes of man's emmet-like race. As there can be little doubt that the glacial conditions to which these blocks testify, were induced mainly by the simple elevation of the whole Himalayan area, so there can be equally little doubt that such elevation was effected without materially affecting the grander orographical features of the country, and hence it comes that we must picture to ourselves as the agent employed in their transport a mighty trunk glacier, debouching somewhere above Bubhor, after a course of some 350 miles, a spectacle unmatched for grandeur at the present day in the loftiest regions of either hemisphere.

Without pursuing farther all the arguments which might be adduced, it will suffice here to summarise the conclusions which may be drawn from the glacial phenomena of the Kángra district—

1st.—That prior to the deposition of the Sivalik group, the whole Himalayan area stood at an elevation not less than 12,000 feet and perhaps 15,000 feet, higher than at present.

2nd.—That in consequence of this superior elevation, the whole of the Sub-Himalayan region north of the Duns (which had then no existence) exceeding 1,500 feet elevation, was subject to the incursion of glaciers, which from the magnitude of the drainage area whence they descended were of the most colossal proportions.

3rd.—That the Sivalik period was marked by a subsidence of the whole Himalayan area, a corresponding retrocession of glacial conditions, and a return, during the reign of the Sivalik fauna, to conditions not very dissimilar to those now obtaining in the region.

NOTE.—There are many features in Mr. Theobald's paper very tempting for the critic; but they must be left to the intelligence of the readers. One omission he has made is fairly open to

editorial comment; the more so, as it affords a most instructive illustration of what threatens to become a very serious stumbling-block in geology, involving, as it does, the ignoring, abandonment, or even the inversion of the fundamental principle of the science. The evil indicated is, the blind adoption, or application, of the homotaxeous method in the classification and nomenclature of formations.

Glacial phenomena, and the 'glacial period,' having been lately very prominently under discussion, it will astonish many that in a paper treating specially of the former enormous extension of the Himalayan glaciers, no mention should be made of the possible connection of this fact with 'the glacial period'; the sole cause assigned for the case of the Himalaya being a supposed greater elevation of from 12,000 to 15,000 feet. The local time assigned by Mr. Theobald for the Himalayan glacial period may be correct: there is no doubt of its being posterior to the disturbance of the Náhan group, and to the excavation in it of the existing drainage system; and the reason given for its being anterior to the Sivalik group (as properly restricted by Mr. Theobald) is at least plausible. But here the fallacy steps in: the Sivalik formation is 'pliocene'; the 'glacial period' is 'post pliocene'; it is therefore needless to consider the relation of the latter with the prepliocene glacial period of the Himalaya, as well attempt to identify it with our Talchir (palæozoic) glacial period.

It is enough to state the case, to show the danger of it. Palæontologists are cutting themselves adrift in loosening their hold upon the chain of physical causation. Are they in a condition to say that even the Sivalik fauna (as restricted) *could* not be contemporaneous with the post-tertiaries of Europe, as is implied in the above argument?

It is plain that the possible, not to say probable, connexion of the glacial periods here and in Europe offers an incomparable means of fixing the contemporaneity or correspondence of the extinct faunas of such distant regions. The importance of this possibility will not be lost sight of.—EDITOR.

ON THE BUILDING AND ORNAMENTAL STONES OF INDIA, *by* V. BALL, M. A., *Geological Survey of India.*

In the year 1871, when at home on leave, my friend Professor Hull, Director of the Geological Survey of Ireland, informed me of his intention of bringing out a work on BUILDING AND ORNAMENTAL STONES, and invited my assistance in reference to the portion of it treating of India. Fortunately my promise of assistance was made conditionally upon my having leisure sufficient to hunt up all available authorities on the subject, as since 1871 up to the present time (April 1874), I have been almost constantly on the move, and during the short periods I have spent in Calcutta my time has been taken up by other more pressing occupations, so that I have found it utterly impossible to attempt to do anything like justice to the subject.

Professor Hull's book having been published in 1872, the present notes are printed in the Records as an instalment of what may hereafter be written. In a country covering so large an area as India, and where, in spite of the comparatively little use made of stones in modern British buildings, building stones have been employed for a long period of time by the natives, ample material exists for a very much more extensive account than the present. My chief difficulty has been to compress the principal facts within the limits available for the purpose.

By giving full references to the principal authorities on the subject, the reader is placed in possession of a means of acquiring fuller details than there is room for in the present account.

Character of Anglo-Indian buildings.

Throughout the Gangetic valley the public buildings which have been erected under the auspices of the British have until quite recently been built almost exclusively of bricks. In many cases the difficulty of obtaining a building stone within an easy distance of the towns situated in the alluvial valley, and in all the consideration of primary economy, have led to the employment of perishable bricks instead of lasting stone in the construction of our officers' courts, private residences, &c.

Even in parts of the country where good building stones are to be obtained, bricks are often the only material regularly used.

It is no doubt this feature of Anglo-Indian architecture which in part gave rise to the saying that if the English left India, in a century after their departure no sign of their occupation, save that afforded by a few empty beer bottles, would remain.

Architectural results from the use of bricks.

Unfortunately the use of bricks cannot be justified even by the appropriate or ornamental character of the results. If durability is sacrificed, we are justified in asking if not for ornamental structures at least for buildings calculated to make this trying climate somewhat more endurable. But what do we find? To quote the words of Major (now Colonel) Medley: "Who does not know the scene of desolation that comes over one at first sight of some of our Indian cantonments: the straight and dusty roads, the rows of glaring white rectangular barracks, the barn-like church differing only from a barrack in the presence of a square tower and classical! portico, the Roman Catholic Chapel ditto, only smaller and with bright green doors all round"? and again: "It must, I think, be allowed that the true principles of architectural construction for buildings in the east, which are to be used by men habituated to an entirely different climate, have not as yet been discovered; a mosque, for instance, has a pleasant temperature both in winter and summer, while a Gothic church in India is, as a rule, either very hot or very cold. I do not say that Gothic churches are unsuitable to India, but only that they are so as we now build them."*

Native buildings suited to the climate.

Temples and houses built in the native style, though often somewhat close and ill ventilated, are generally considerably cooler than any European buildings. This is particularly true of the massive stone structures of the north-west.

Evidence of durability of material afforded by native buildings.

In new countries, such as Australia and America, the engineer or architect often experiences a difficulty in determining the durability of materials which he may wish to employ. Even in England this difficulty is not unknown, as is evidenced by the failure of the stone used in the construction of the houses of Parliament; but in India, in the civilized parts, wherever building material occurs, ancient temples or other native buildings are almost sure to be found. These furnish all the information which can be required as to the durability of the stone when exposed to the atmosphere.

Other qualities admit of speedy tests.

The other qualities in building stones—strength, appearance, and susceptibility for ornamental treatment—can all be determined by simple and readily applied tests; but there is no known speedy test of durability.

Causes of disintegration.

The presence or absence of certain minerals, or some peculiarity in the structure, are causes sufficient to determine the decomposition, which may be more or less protracted, but which must eventuate in the disintegration of the stone and the consequent disfigurement, if not total destruction, of the building in which it has been employed.

* Prof. Papers on Indian Engineering, Vol. I, pp. 201-2.

With examples of stone work which range in age from before the Christian era up to modern times, the engineers and architects of India have an immense advantage over those of newer countries.

Care requisite in selection of material.

It should be scarcely requisite to observe that the proof of a certain formation affording good building stone is not sufficent to justify the conclusion that all the stone of that formation is equally durable. Yet the passing of individual blocks of stone is under these circumstances, there is reason to believe, often performed in an imperfect manner. Cases might be quoted where ill-chosen stones have not proved equal to the work which might justly be expected from the material had a little care been used in the selection, and thus, too often, a material has received a bad name and evil reputation where in truth its qualities have not been put to a fair trial.

Skilled stone-workers more numerous formerly.

Although locally, in the construction of bridges and other works where stone has been employed, vast numbers of coolies have been trained so as to become very fair stone-cutters, still the number of highly *skilled* artizans is probably less than it was in former times, when the inhabitants of almost every district in India into which Aryans penetrated erected their temples of stone. In many cases these temples, to the present day, exhibit admirable workmanship in the most difficult materials.

The building stone resources of India undeveloped.

To show how little has been done towards developing and rendering these resources of India available, it is only necessary to refer to the grim advertisements which daily meet our eyes in the newspapers, of tombstones of Aberdeen granite and Italian marble.

In further illustration of this, I may mention that at Ránigani, 120 miles inland from Calcutta, I have seen at the potteries enormous granite mill-stones for crushing quartz which had travelled probably 15,000 miles to their present destination, while within a radius of 20 miles several places could be indicated where stone suited to the purpose could be obtained were quarries only opened up.

Prospect of future development.

With increased facilities for carriage, by rail and canal, and with some modification of the traditions in favor of Public Works Department bricks, we may yet look forward to a time when the splendid building materials existing in India * will be brought into more general use for our public and private buildings. And we may thus yet hope to see structures of an ornamental and lasting character worthy of our position in this country.

The order in which the several classes of materials are arranged in this paper is that followed by Professor Hull—

I.—GRANITIC AND GNEISSOSE ROCKS.
II.—BASALT AND TRAPS.
III.—SERPENTINE, POTSTONES, AND SOAPSTONE.
IV.—MARBLE.
V.—GYPSUM AND ALABASTER.
VI.—ORNAMENTAL STONES.
VII.—LIMESTONES, KUNKUR.
VIII.—SANDSTONES, QUARTZITES.
IX.—LATERITE.
X.—SLATES.

* Some trials of indigenous limestones from the Vindhyans and from Karnúl for lithographic purposes appeared to give promising results; but the large quantity of stones which are used in the Presidency towns are still, I believe, exclusively imported from Europe.

I.—GRANITE AND GNEISS.

Most of the so-called granite of India is a granitoid gneiss, a resultant of the excessive metamorphism of sedimentary rocks. To what extent true eruptive, igneous granite occurs in the peninsula is quite unknown. Granite, which from its physical relations one may venture to conclude is of truly igneous and eruptive character, is not however absent. But, as a rule, the physical relations accompanying exposures of perfectly unfoliated granites in the metamorphic areas of India are not of a sufficiently definite character to enable one to assert with confidence the nature of the origin of those granites. There is no crucial test which can be applied to determine this question. Even microscopical examination of the minerals is not now considered to afford in all cases an infallible guide. But even if it be, it is not of easy application, and cannot be made use of in the field.

These remarks seem a necessary preface to the following account, as travellers and antiquarians, who have described buildings, have not often attempted to characterise, more than by some very general term, such as granite or sandstone, the materials of which those buildings have been constructed.

The metamorphic rocks occupy a very considerable area in India.

East of a line drawn from Rotásgarh on the Són through Umarkántak to Goa, the greater part of the country consists of metamorphic rocks. The younger rocks which do occur in that area are for the most part limited to comparatively inconsiderable basins. Metamorphic rocks, not to mention small exposures within the limits of the great basaltic flows of Western India, also occur in Bandelkand, Kach, the Gáro and Kásia Hills, and in the Himalayas. Whether these all belong to the same age or not is a question of much difficulty and uncertainty. The probability is that they do not. Lithologically there is sufficient general resemblance to justify their being all classed together in this account.

The varieties of materials suited to building purposes are of course very numerous. There are those caused by structure and those due to composition. By the former character they are divisible into foliated and non-foliated. The simplest form of the latter is a binary compound of quartz and felspar, or pegmatite, sometimes appearing as graphic granite. Then there are the ternary compounds, consisting of the two minerals just mentioned, with the addition of mica, hornblende, or talc, which are known respectively as granite, syenite, and protogine. Various modifications of these four varieties are produced by the presence of foreign minerals, such as, oligoclase, schorl, garnet, epidote, magnetic iron, &c.

As building stones the dense crystalline unfoliated varieties are the most durable. The presence of garnets or magnetic iron is likely to be detrimental, as these minerals under the influence of the atmosphere are apt to disintegrate, and so mar the appearance, if they do not ultimately endanger the stability, of the edifices in which stone containing them is employed.

I shall now endeavour to give some enumeration of the principal localities where these rocks have been used for the supply of building stones, and point out the features of the principal examples.

In the alluvial tracts of Bengal ancient buildings of stone are of most uncommon occurrence. Towards the west, however, in the rocky districts and on their borders, evidence is not wanting that the art of working in stone was practised whenever the material was available. In the Ganges close to Colgong there are several small hills which form islands in the present bed of the river. These hills consist of piled masses of a very compact grey granite, which in olden times used apparently to be resorted to for material for the construc-

tion of temples. The old holes for the wedges are still to be seen, and one enormous slab, which was partially split off, was never removed, and still clings to its place.

In Behár many temples are to be found in the construction of which granite was employed. At Gya some of the Buddhistical rails and the floorings of temples, &c., are of granite.

At Barábar Hill occur, so far as I know, the only instances of artificial caves excavated in these hard rocks. In sandstones and trap, as we shall see hereafter, not a few instances can be quoted.

Throughout the Chutia Nágpur Division sandstones are generally more or less accessible, so that temples built of granite are of by no means common occurrense. But as we proceed southwards along the eastern coasts from Midnapore through Orissa, the use of granite seems to be more and more common.

At Neeltigur Hill, in Pergunnah Ultee, in Orissa, Hindu temples and deities are of garnetiferous gneiss, as are also some large figures in the Black Pagoda at Pori.

On Mahendragiri Hill, in the district of Ganjam, I observed an example of what I have since been informed was not uncommonly the practice with regard to the construction of these temples. On the top of the hill is an unfinished temple built of huge blocks of porphyritic gneiss, which on their exposed faces are rough and uncut. The practice appears to have been, not to have attempted any ornamental work until all the stones of the building were in position and then to have pared them, so to speak, into shape. One of the stones which I measured in this temple had the following dimensions, 9′ × 3′ 9″ × 3′, which would indicate a weight of about 8 tons.

The natives get over the difficulty of accounting for such megalithic structures by asserting them to be supernatural, or by saying that "there were giants in those days."

In his report on the Nilghiri Hills, Mr. H. Blanford pointed out several places where excellent building stones could be obtained from the crystalline rocks. But not much use has hitherto been made of them. In Mysore a variety is obtained, which is split into posts 20′ long, which are used for the support of the electric telegraph wire. As readily accessible examples of the useful and ornamental purposes to which the gneisses of Southern India have been put, Mr. King instances the following:—

A polished slab of quartzo-felspathic gneiss in the Durbar hall in the Rajah's palace at Tanjore, which measures 18′ × 16′ × 2′ 1½″.

A small temple in the north-west corner of the Pagoda Court at Tanjore, which is "a perfect gem of carved stone-work," the elaborate patterns on which are as sharp as when they left the sculptor's hands.

Other beautiful examples of carving are to be seen at the Rock Pagoda of Trichinopoli, at Volcandapuram, and at the Chellumbrum Pagoda. "Even at Trivalur near Negapatam, at the eastern extremity of the great delta of the Cauvery, nearly sixty miles from the nearest gneiss quarries, the great pagoda and tank are surrounded by walls of massive gneiss."

"As an instance of the peculiar susceptibility of gneiss to fine carvings, the rings appended to the drooping corners of some pagoda buildings may be mentioned. These rings, the links within which are moveable, and the projecting corners, are carved out of single blocks of gneiss, such as may be seen at the Strimustrum Pagoda."

Mr. King also mentions the use of blocks of gneiss in the construction of walls, *bands* of tanks, beach groynes at Tranquebar, culverts, bridges, &c.

The ancient Druid-like remains called Karumbar rings which are found in various parts of Trichinopoli generally consist of rough blocks of gneiss. In parts of Chutia Nágpur old settlements of the Kols made use of gneiss in the erection of *Menhers* and *Dolmens*. But, at the present day, the Kols who erect such memorials for the most part dwell in a part of the country where flags of schist and slate are readily accessible, and they therefore do not use gneiss.

In Madras Mr. Foote says that the beds of very hornblendic gneiss which occur "at Palaveram, Cuddapary Choultry, and Puttandulum are largely quarried for the manufacture of articles of domestic use as well as for building purposes."

Other varieties in different localities in Madras are mentioned; some of these have been quarried to a considerable extent.

Except for purely local purposes, the construction of bridges, &c., where, upon economical grounds, the rock nearest to hand has been made use of, the varieties of granite, gneiss, &c., on account of their hardness, have not commended themselves as building materials to English engineers. So far as I know, there are, throughout the country, no British buildings of importance, in the construction of which these materials have been used.

References.

	Orissa	...	... Mem. Geol. Surv., India,		I, p. 277.
Blanford,	Nilghiris	...	...	" "	p. 244.
King,	Trichinopoli	...	...	" "	IV, p. 367.
Foote,	Madras	...	...	" "	X, p. 131.
Balfour's Cyclopœdia, Art. Granite.					

II.—Basalt.

Trap.—Any one who has paid attention to the subject is aware that the greater part of Western India, the Dekan, and the Central Provinces is occupied by a vast accumulation of eruptive rocks which are generally spoken of as Dekan trap. From north to south these rocks extend from a point 100 miles south of Gwalior to the vicinity of Goa, and from west to east from Bombay to Umerkántak, thus covering an area of about 1-6th of the peninsula, south of the Ganges. Roughly estimated, we may put down the area in which these rocks prevail at 200,000 square miles.

On the eastern side of the peninsula too, rocks, which, without going into details of the mineral constituents, may be conveniently spoken of generically as trap, occupy a by no means inconsiderable area, as in the Rajmehal Hills.

From the evidence afforded by the sedimentary beds with which these rocks occur interbedded, those in the west appear to be referable to the close of the cretaceous epoch, while those of the east (Rajmehal) belong probably to the jurassic.

The whole of the trap rocks which are used for building purposes are not, however, exclusively derived from the two above-mentioned sources. In many other of the recognised formations in India the trappean rocks occur as dykes; sometimes these are basaltic, but, in the older formations, diorites prevail.

In the Dekan and Rajmehal areas, other rocks are not altogether absent, as there are not only the sedimentary, interstratified rocks above mentioned, but also, on the outskirts, the deeper valleys occasionally disclose rocks of older formations.

The former, however, are not generally suited for building purposes,* and are therefore less used than trap, which, though sometimes difficult to cut, is, if well chosen, a most durable material, and is moreover susceptible of much delicate and artistic treatment.

As might be anticipated in the Dekan area, from the enormous thickness of these rocks which occur, the lithological varieties are numerous. These varieties are due both to differences in mineral composition and degrees of compactness.

With regard to the relative adaptability to building purposes of the various kinds of rock which are most commonly met with, Mr. Blanford remarks: "None of the beds containing zeolites, interspersed in irregular strings and veins throughout the mass, are good. They are too soft, brittle, and liable to decompose. None of the ash beds are equal in strength, toughness, or resistance to the atmosphere to the solid basalts, and no rock of a red colour should ever be taken for building purposes. It is almost always decomposed. Amongst the very best beds are the porphyritic basalts, such as those which form so large a proportion of the rocks on the Thull Ghât."

Mr. Bell says:—"The best I should consider to be the bluish-green basalt, which is very hard and heavy, having a specific gravity about 3·0, and which rings like a metal on being struck."

Probably the first use to which the trap rock was put in India was in the manufacture of stone implements or celts, of which specimens are occasionally found, in some cases far removed from the places where the rocks occur.

To a very early period must be referred that form of architecture which consisted in hollowing out and sculpturing the rock *in situ* into temples and dwelling places, of which we have magnificent examples in the caves of Adjanta, Ellora, and Elephanta. These caves contain sculptures and inscriptions indicative of their Buddhistical or early Brahminical origin. Several of these caves are assigned to a period from 200 to 150 years B. C.

At Gya, according to General Cunningham, some of the Buddhistical *rails* are made of basalt, others being of granite and sandstone.

Coming down to a more recent period, we find on the eastern side of India trap from the Rajmehal Hills made use of for lintels and door posts in Hindu temples, and not unfrequently for the images contained inside. Trap used in this partial manner may be seen in many of the old buildings in the vicinity of Rajmehal and the ruined city of Gaur: occasionally, too, in temples in the Burdwan District. The black marble of many writers is probably only this material. When covered by the native offerings of *ghee*, it is often, without doing what in the sight of the people would be regarded as desecration, impossible to make out the material of which the images are made.

In the famous Black Pagoda at Pori trap is said to have been much used. This material was probably derived from dykes in the metamorphic rocks.

In the Dekan and surrounding trap country this material has been used in the construction of forts and native buildings of various kinds.

One of the most magnificent works in trap is stated by Dr. Balfour to be an unfinished tomb of one of the Gwalior princes at Poona.

Recently it has been extensively used in the construction of bridges and stations on the lines of railroad which traverse the trap country, but I understand that from causes for which the stone is not altogether in fault, but rather the lime and workmanship, the work has not given complete satisfaction.

* An exception will be found noted on a following page.

In the city of Bombay trap has been used to some extent, but chiefly in rubble masonry. All the finer buildings in Bombay are constructed of a very different material, as will be mentioned in its proper place.

The principal use to which the trap rocks of the Rajmehal Hills are at present put is for the supply of Calcutta with road metal.

References.

Building materials, Bombay Island, Carter's Geology of Western India, Bombay, 1857, p. 161.

Building stone in Western India, Merewether, Prof. Papers of Ind. Eng., Roorkee, Vol. VI, 1869, p. 130.

Geology of Bombay Island, Wynne, Mem. Geol. Surv., Ind., V, 1864, p. 173.

Geology of Western India, Blanford, Mem. Geol. Surv., Ind , VI, 1869, p. 379.

Masonry in a trap country, H. Bell, Prof. Papers of Ind. Eng., Roorkee, Vol. I, 2nd Series, 1871, p. 162.

III.—SERPENTINE.

Serpentine in sufficient quantity to be deserving of mention in this enumeration is of rare occurrence in India. In the sub-metamorphic rocks of Western Bengal, I have occasionally met with it in small quantities. In the district of Singhbhum, south of the station of Chaibassa, it occurs in beds of a white limestone.

In the Madras presidency, in the eastern part of the Kadapa District, a beautiful serpentinous marble is said to occur, but it has not been much used hitherto.

Dykes of serpentine, possibly the result of alteration of some original igneous rock, occur most uncommonly in the tertiary sandstones of the Andaman and Nicobar Islands. Some of the purer varieties might, if obtainable in large blocks, be used for ornamental purposes. A black variety streaked with green, which occurs at the head of Port Blair, particularly attracted my attention. So far as I know, no attempt has been made to work it.

Serpentine is said to be found in parts of Upper Burma, where it is worked and exported to China.

Potstones.—Chloritic schists, passing, on the one hand, into talcose, and, on the other, into serpentinous rocks, occur not uncommonly in the sub-metamorphic and somewhat less frequently in the metamorphic series.

In buildings the varieties of this material have only been used on a small scale for ornamental purposes, for which some of them, as being tough and at the same time easily carved, are particularly suited. More extensively they are used in the manufacture of altars, idols, plates and bowls.

In the southern part of Mánbhum, on the frontiers of Singhbhum, there are numerous workings, which generally take the form of narrow mines which are deserted during the rains. From these mines a considerable quantity of stone is annually extracted; the blocks are roughly dressed to the shape required, be it for *Lingam*, plate or bowl. They are then fixed in a rude lathe and cut into form and given a smooth surface. When finished, they are carted off to Burdwan, where they are in great demand, and a portion are sent on to Calcutta for sale.

In the neighbourhood of Gya too, there are many large mines and quarries of this stone, which supply a considerable trade in idols and utensils.

One class of the varieties used stands fire well, while the other does not. The former is of course the most esteemed by the natives. The cracking of the latter is probably due to the water of combination in the more chloritic varieties, which becomes released on the application of heat.

In many of the ancient temples in Chutia Nágpur images made from this material are not uncommonly met with.

The beautifully sculptured doorways of the Black Pagoda near Pori are of this material, which was probably obtained from the Nilghiri Hills in Orissa.

In some of the more finished temples at Bobaneswar there are large well polished and highly sculptured slabs of potstone let into the walls. (Stirling).

In parts of Trichinopoli these rocks are applied to similar purposes.

Soap-stone.—The very beautiful steatitic material so much used for delicate carvings in Agra, though generically related to the rocks mentioned under the above head, seems deserving of separate notice in this enumeration.

This rock is obtained in the territories of the Raja of Jaipúr. In Agra it is chiefly used in the manufacture of small ornamental articles, but has not yet entered into use as a material for architectural decoration, although it is admirably suited to the purpose.

Reference.

Keene—On the Stone Industries of Agra.

IV.—Marble.

Marble in India is better known from its great beauty in the few places where it does occur and its successful employment in the ornamental architecture of some of the cities of North-Western India, Rajputana, Guzerat, and a few other places, than from being generally distributed throughout the country.

The Taj at Agra which was erected by the Emperor Jehangir, to the memory of his favorite wife Nur Jehan, is built of polished white marble, and is by many competent authorities considered to be one of the most beautiful and perfect structures in the world.

The material for this glorious monument, as well as for many others, was obtained in the Jaipúr territories.

But the special purpose to which the marble of Jaipúr has been put, and for which it is so admirably suited, is the manufacture of screens, the delicacy of the tracery on which can in many cases be only compared with lace. This work is known by the name *Jalee.* Besides marble, sandstone is sometimes, however, employed for this purpose, as the following description by Mr. Keene will show: "It is a fine filagree of marble or sandstone fretted into an almost endless net-work of geometrical combinations, such as can only be understood by seeing the carvings themselves or good photographs of them."

In the opinion of Mr. Fergusson, the *Jalee* work of Ahmedabad in Guzerat is still finer; but the style of the two is quite different.

According to Mr. Keene, the finest example of this form of work to be met with in Northern India is the following; he says: "But all the marble-work of this region is surpassed by the monument which Akber erected over the remains of his friend and spiritual counsellor Shekh Suleem Chistee at Fatipúr Sikri (1581 A. D.). In the north-western angle of a vast courtyard 433 feet by 366 feet is a pavilion externally of white marble, surrounded by a deep projecting dripstone, of white marble also, supported by marble shafts crowned by most fantastic brackets shaped like the letter S. The outer screens are so minutely pierced that they actually look like lace at a little distance, and illuminate the mortuary chamber within with a solemn half-light which resembles nothing else that I have seen. The whole of this elaborate work, including the strange but most pleasing design of the brackets, appears to have been produced by the resident stone-cutters

of the place—uneducated men earning probably an average wage of about a penny a day. I believe that no instance of such pure patient workmanship, so dignified, yet so various, is to be found in the world." In a very beautifully illustrated Work on the Architecture of Ahmedabad by Mr. T. C. Hope, B. C. S., with architectural notes by James Fergusson, photographs illustrative of this work and of buildings in sandstone will be found; many of these buildings are comparatively modern, and some are quite recent. It would appear that the art of working in these materials has been more fully conserved in Guzerat than in any other part of India. But it has been by no means lost or even discontinued, though it is not extensively practised now in the northern cities.

I am informed by my friend Mr. Hacket that at Rialo in Jaipúr the *Jalee* is still made, and that the traceries in it are as delicate as any which are to be seen in the Taj. Other quarries near Jaipúr are also in operation. In the "Hand Book of the economic products of the Punjab," by Mr. Baden H. Powell, there is a list of marbles of which the following are the principal: (1) an inferior marble which, however, takes a good polish from Narnul, in the Pattiala territory; (2) grey marble from Bhunsi; (3) black marble from Kashmir; (4) white and veined marble from Sardi in Jhelum; (5) yellow marble from Manairi, Yusufzai.

In the Narbada valley, the marble rocks, justly famous for the excessive beauty of the deep gorge cut through them by the river, consist of a tolerably pure white saccharine limestone. This is the strongest local development of the calcareous element which occurs with the schists in the Bijour series of rocks.

The marble, except locally in some of the temples, has not been used for building purposes. It is much jointed on the surface, and has been a good deal crushed by tilting into the present vertical position of its beds and by the trap dykes which traverse it. But it seems probable that large blocks might be extracted, and it is possible that portions might be obtained of sufficiently fine quality for statuary purposes,* but I am not aware of any attempt having been made to use it in this way.

I must add, however, that according to Dr. Balfour's Cyclopœdia, a block sent to the Paris exhibition of 1855 (?) was pronounced to be equal to Italian marble for statuary purposes.

Several localities in Bengal might be mentioned, where more or less pure crystalline limestones occur, but these are not of much economic importance. Silica, tremolite, and serpentine are the chief foreign minerals which occur in these crystalline calcareous rocks.

In his work on building stones, Mr. Hull mentions among other localities Syepore, Gya, and Durha in Bengal as localities where marble occurs in India. The name Syepore (whence the mineral called Syeporite) has its origin in a clerical error, and the names should stand as Jaipore or Jaipúr, as it is now spelt, and Jaipúrite. I am not aware of any marble being found at or near Gya, though the black basalt used in the temples there may very possibly have been so called by some visitor or antiquarian. As for Durha I am quite unable to trace any place bearing the name in Bengal proper. Possibly it may be Dura, near Bhurtpúr, in the Agra district of the North-Western Provinces. If so, the marble in use there probably comes from Jaipúr.

In the Khasia Hills it is said that much of the nummulitic limestone would produce most durable and occasionally very handsomely veined marble. It would answer well for ordinary purposes, chimney-pieces, slabs for tables, garden seats, and for flooring tiles.

In Southern India there are several well known localities where more or less ornamental and durable marbles are obtained; samples of these have been from time to time collected,

* Some parts are obviously too silicious to be so employed.

polished and exhibited both in Madras and Europe; favorable reports have been published, and there the matter has been allowed to rest.*

In the Palnad, according to Mr. King, there are some particularly well colored marbles. There are also breccia beds of various colors " in the western scarps of the Jummulmudgoos and the bottom of the slates in the Chey-air field." Dr. Balfour describes the marbles of the Kadapa District as being of various shades of green.

At Coimbatore, according to Mr. H. Blanford, there are crystalline limestones "susceptible of a high polish, and very transparent, which would afford a very beautiful material for internal decorations, the effect of which would be enhanced by the judicious selection of slabs of various tints. Pink and grey, occasionally approaching white, are the prevailing colors of the stone."

In Burma, for statuary purposes, marble is largely employed. The material for the well known sitting and recumbent figures of Gaudama is said to be obtained chiefly from the Tsygen Hills near the village of Mowe in the district of Madeya.

References.

Medlicott, J.—Nerbudda	...	Mem. Geol. Surv., India,	II, p. 135.
Oldham, T.—Khasia Hills	...	" "	I, p. 185.
Blanford.—Coimbatore	...	" "	I, p. 247.
King, W.—Trichinopoli and Kadapa		" "	IV, p. 370, & VIII, 282.

Keene.—Agra—Stone Industries of Agra.
Powell, B. H.—Punjab—Punjab Products.
Balfour.—Madras, &c., Art. Marble—Cyclopœdia.

V.—GYPSUM.

As a building stone gypsum has been very little used in India. To some small extent it is manufactured locally, where it occurs, into ornaments, and is occasionally employed for mixing with lime to produce a hard and shining surface on chunam work. The manufacture of plaster of Paris from calcined gypsum appears to be unpractised by and unknown to the natives.

Gypsum in quantities of importance and deserving of notice is found only, so far as I know, in the Salt Range in the Punjab, parts of the Lower Himalayas, Spiti, Kach, and Madras.

Its manner of occurrence at these various localities varies much.

In the Salt Range, according to Dr. Fleming,† gypsum occurs scattered in irregular beds and huge mass throughout the marl in which rock-salt also occurs. It is "for the most part of a light grey color, with a shade of blue and translucent' on the edges. It has a saccharine appearance, but masses in which a coarse crystalline structure prevails are by no means uncommon. Red varieties also occur, and beds of a dark grey earthy gypsum are generally associated with the saccharine kind."

It is said to be very abundant at Pind Dadun Khan. It also occurs at Mari, Kalabagh, and Surdi, where it contains quartz-crystals of various colours, which are known as Mari diamonds, and are much used by the natives for necklaces, &c. The marl on Mount Kuringil is also said to contain abundance of gypsum.

Dr. Fleming suggested the gypsum of Pind Dadun Khan being made use of by the Public Works Department for building purposes.

The marl in which this gypsum occurs is considered to be of silurian age.

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* According to Mr. Balfour's Cyclopœdia: "Specimens sent to the great exhibition in 1851 were favorably reported upon as indicative of a valuable material, adapted to sculptural and ornamental purposes.

† Jour. As. Soc., Bengal, XXII, p. 250.

In Mr. Medlicott's account of the Sub-Himalayan rocks of North-Western India* he states that gypsum occurs in several parts of the district; it is found in lumps in the ferruginous clays of the Subathu group, and at Sahansádhara, below Masuri, it occurs in small irregular veins through limestone.

Mr. Mallet has described the deposits of gypsum in the Spiti valley. He believes them to be derived from thermal springs, as the masses occur at all levels unstratified and amorphous, and what is more to the point, the thermal springs are at present depositing gypsum with the carbonate of lime. The origin is traced to chemical reaction between† iron pyrites and carbonate of lime, the former abounding in the underlying black slates.

Mr. Mallet concludes his observations thus: "The compact unaltered portions of the gypsum are of a snowy whiteness, and would form a beautiful material for ornamental purposes. All of it, from its apparent purity and freedom from iron, &c., might be manufactured into very superior plaster of Paris. One fatal bar, however, exists to its economic employment, namely, the mountain carriage across the entire breadth of the Himalayas."

In Kach Mr. Wynne‡ reports the existence of gypseous shales below the regular nummulitic beds; but the deposit of gypsum appears to be inconsiderable there.

In Madras gypsum occurs in several places. "It is most abundant in the Ootatoor beds (cretaceous), especially in the belemnite clays to the east of Ootatoor and in the unfossiliferous clay to the north-east of Muravuttoor.§

It might be obtained in any quantity for ordinary purposes, such as moulds; but for casts it is generally too impure; however, selected portions, chiefly in the form of transparent plates of selenite, would answer for a small demand for the latter purpose.

Dr. Balfour, in his Cyclopœdia, besides the above, also enumerates the following localities. The Chingleput District, Sadras, Ennore, the Red Hills, Nellore, Masulipatam, and Bangalore.

Gypsum is used by the natives medicinally, and can be obtained in most bazars in small quantities.

VI.—Ornamental Stones.

The use of ornamental stones in buildings in India, either in the way of mosaic or on a larger scale, has not been much practised latterly.

Probably the finest extant example is afforded by the inlaid work in the Taj at Agra. The following is a list of the stones used there as ascertained by Dr. Voysey:—

Name.	*Locality.*
Lapis Lazuli	Ceylon and Thibet.
Jasper	Basaltic trap of Hindustan.
Heliotrope	Basaltic trap of Hindustan.
Chalcedon Agate	Basaltic trap of Hindustan; also from Sone and Narbada.
Chalcedony	
Cornelian	
Sarde	
Plasma, or Quartz and Chlorite	Basalt of Dekan.
Yellow and striped marble	Guzerat.
Clay slate	?
Nephrite or Jade	?

* Mem. Geol. Surv., India, Vol. III, p. 177.
† " " " V, p. 157.
‡ " " " IX, p. 266.
§ " " " IV, p. 214.

The following passage will give some idea of the elaborate character of these mosaics: "A single flower in the screen around the tombs, or Sarcophagi, contains a hundred stones, each cut to the exact shape necessary, and highly polished; and in the interior alone of the building, there are several hundred flowers, each containing a like number of stones."

In various parts of the basaltic areas of India varieties of agates and jasper occur in considerable abundance, and are collected and sold to lapidaries, who cut them into useful and ornamental articles; but they are not much used for mural decoration or mosaics at the present day. In the valley of the Narbada and Sone such pebbles are found somewhat abundantly. I believe there is no case of the original matrix, the basalt, being worked for them, but the gravelly beds of some of the tertiary rocks, which consist mainly of débris from the basalt, are mined in several places. In Western India the mines at Ruttunpur, east of Broach, are the principal. The stones found there are sold to the lapidaries of Cambay and Jabalpúr.

In the Rajmehal Hills very beautiful agates, common opal, and other varieties of silica are abundant, but are not, so far as I know, sought after or collected.

At Vellum, in Trichinopoli, some tertiary grits contain pebbles of rock crystal, smoky quartz, cairngorm and amethyst, which are cut by the local lapidaries.

References.

Voysey, Asiatic Researches, Vol. XV, p. 429.
Blanford, Mem. Geol. Surv., India, Vol. VI, p. 219
King, Mem. Geol. Surv., India, Vol. IV, p. 370.
Keene on the Stone Industries of Agra, 1873.

VII.—LIMESTONE.

Under the head of MARBLE I have separately described those varieties of limestone which, from their crystalline structure and ornamental appearance, are entitled to be so dignified. In the present section I shall confine myself to an account of the chiefly, but not exclusively non-crystalline varieties which are used or are available for use as building materials or for the manufacture of lime.

By far the most important deposits of rock limestone in the northern portion of the peninsula of India are those which occur in the Vindhyan series. In the lower Vindhyans occurs a group of thin-bedded limestones which in the places where they are best exposed have a total of several hundred feet in thickness. At Rotásgarh it is chiefly quarried for burning. It is brought down the Sone in boats and into the Ganges, by which means it is distributed over a considerable area of country. When the Sone canal is opened this trade will probably become more regular, and it is possible that Calcutta may be supplied from this source, a contingency much to be desired in view of the great expense of Sylhet lime, which is that which is principally used at present.

Attention has been drawn to this limestone too as being, within a reasonable distance, the only source of a material of steady, known composition capable of affording a suitable flux for employment in the proposed iron-works in the Ránigani country.

It should be mentioned, however, that the steady composition can only be depended on in individual layers, as the proportion of associated argillaceous matter varies in successive layers.

This rock has been traced as far west as the neighbourhood of Katni on the Jabalpúr line; at Múrwára, &c., quarries have been opened where the Jabalpúr railway crosses the outcrop.

Higher in the Vindhyan series the Bandér group includes a limestone which is not only used as a source of lime, but as a building stone in the Dumoh district, where it is preferred to the lower sandstone; the same is said to be the case in the vicinity of Nimach.

Some of this stone was reported on favorably for lithographic purposes, but it has never come into use.

In several parts of Bengal occupied by the metamorphic rocks limestones occur, but they are in general too much impregnated with foreign minerals to be of use either as building stones or as sources of lime.

In the neighbourhood of the Khási Hills the so-called Sylhet limestone is extensively manufactured into lime for the Calcutta market. The principal factories are at Chátak and Sonamganj, and along the banks of the river Súrma between these two villages. The quarries are "near the village of Tungwai or Tingye, from which the stone is brought to the neighbourhood of Pondua and to Chátak. Other very large quarries are in the vicinity of the great orange groves between Teria-ghât and Lacát, from which also the stone is conveyed to Chátak for burning." This limestone is of nummulitic age.

Under the head of marble will be found a notice of the portions of it which come under that denomination. How far it has been used as a building stone, locally, I have no information, but there is no reason to doubt that good building stone could be obtained.

In Western India limestones occur in the metamorphic and the Bijour series; they are, however, usually too silicious to be employed in the manufacture of lime, and I can find no notice of their being employed as building stones; but some of the highly calcareous Bágh beds and the nummulitic limestones of Guzerat are used to a certain extent. Regarding the latter, Mr. W. T. Blanford says: "It is difficult to obtain it in large masses, or to trim it neatly. It is employed by the natives for bowries, temples, &c., other compact calcareous beds being used for the same purpose."

In the north-west of India the limestones of the Lower Himalayas are, some of them, applicable to building purposes, and "some fit for ornamental or monumental purposes might be found among the thick-bedded, hard limestones of the Krol group."

The lime in this area is chiefly made from a porous tufa, which occurs along the flanks of the limestone ridges.

In Southern India limestones of at least three distinct geological periods are used as building stones. The oldest of these are the crystalline limestones of the metamorphic series. At Coimbatore there is a limestone belonging to this series which has attracted some attention, as it would make a good building stone as well as being a source of lime; while portions are highly ornamental, as is mentioned under the head of marble. This limestone is described by Mr. Blanford in the Memoirs of the Geological Survey, and at greater length in the Madras Journal of Science. Mr. King also, in his Geology of Trichinopoli, mentions this rock and gives some additional localities. He states that it has been used as a building stone in connection with the Madras and Beypúr railway, and has given complete satisfaction.

The two series of metamorphosed rocks occurring in Southern India, and which are known by the names Kadapa and Karnúl, each contain limestones. For building purposes those of the latter seem to be the most important. The Karnúl series belongs, it is considered, to the same general age as the Vindhyan of the northern parts of India. Mr. King remarks in reference to these rocks. "The limestones, where they are at hand, have been largely used by the people of the country, the larger villages in the Khoond-air valley having their better houses built of well-selected and dressed Nergee beds, while the wells of the Kadapa and this valley are all lined with this stone." Mr. King anticipates that the railway and canals will tend to develope the use of these building materials.

There are still to be mentioned the limestones of cretaceous age which occur in Southern India. These are of two kinds, one being purely sedimentary, the other derived from coral reefs. As building stones they are somewhat extensively used by the natives, but, according to Mr. H. Blanford, "are ill qualified for exposed exteriors, where they rapidly yield to the heavy tropical rains."

References.

Mallet	...	On the Vindhyan series, Mem. Geol. Surv., India, VII, p. 113.
Oldham	...	Khási Hills, Mem. Geol. Surv., India, I, p. 181.
Medlicott	...	Lower Himalaya, Mem. Geol. Surv., India, III, p. 176.
Blanford, W. T.	...	Western India, Mem. Geol. Surv., India, VI, p. 390.
Blanford, H.	...	Southern India, Nilghiri Hills, Mem. Geol. Surv., India, IV, p. 204, and I, p. 246.
King, W.	...	Trichinopoli and Karnúl, Mem. Geol. Surv., India, IV, p. 370, and VIII, p. 282.

Porebunder Stone or Miliolite.

The name miliolite was given by Dr. Carter to a rock which is found in the neighbourhood of Porebunder in Guzerat. Though somewhat oolitic in structure, it is not of oolitic age, and therefore the above name was given to distinguish it.

It is considered to be of newer tertiary, probably pliocene age. In Guzerat its greatest development is in the Gir Hills, where, as also in some of the valleys, it rests upon an arenaceous clay. It is a wide spread deposit, and is said to occur on parts of the coast of Arabia and in Kach.*

As it appears in Guzerat it is a somewhat coarse calcareous grit, abounding in foraminifera towards the west, but containing fewer organisms, and being more argillaceous towards the east. As a building stone it is admirably suited to many purposes, but is said to be incapable of sustaining great pressure. It is largely quarried about twelve miles from Porebunder, from whence it is shipped to Bombay and other places.

In Bombay it has been largely used for building purposes, more particularly in the construction of the recently erected Government buildings.

References.

Carter	... ...	Geology of Western India.
Theobald	... ...	„ Guzerat, M. S.
Wynne	... ...	Kach, Mem. Geol. Surv., India, IX, p. 81.
Balfour	... ...	Cyclopœdia.
Merewether	... ...	Building stone in Western India, P. P. of I. E., VI, 1869, p. 137.

Kunkur or Gutin.

The calcareous concretions which occur in the alluvial clays, and which are known under one or other of the above names, occupy a very important position as a building material, being in very many parts of the country the only source of lime. In addition to this, some of the more massive varieties are used as building stones in parts of India as in the Central Doab.

In the bridges on the Ganges Canal between Rúrki and the Nanún Fork block kunkur has been largely employed, except for the archwork. In the case of the Kasimpúr bridge the external faces of the arches themselves have, however, been made of this material.

In the vicinity of this section of the canal the block kunkur is readily procurable.

Block kunkur was also much used in the bridges on the Fatehgarh and Koel branches of the Ganges Canal. It is thus described by Colonel Sir Proby T. Cautley: "In extremes, the stone may be described, in its most perfect state, as a gray semi-crystalline rock, tough,

* The Kach rock, which has been supposed to represent the miliolite, is, according to Mr. Wynne, devoid of organisms.

with occasional amygdaloidal or irregularly shaped hollows, dispersed through its mass, the hollows being filled with earth. In its most imperfect state (I allude simply to the block kunkur which is available for building purposes) these hollows are more numerous, and they give to the rock a honeycombed appearance to which I have before adverted. It is found in extensive tabular masses or strata (generally accompanied by sand), the upper and lower sides of which are slaty and apparently imperfectly indurated; the induration, in fact, increases towards the centre, where it is frequently of the hardest description of the newest lime rocks, and of a crystalline character."

Owing to the honeycombed surface of the stone, it was found necessary to protect it by stucco from the direct action of the water and of the atmosphere. This rock has also been used, where readily obtainable, in the construction of buildings connected with the railroad.

Block kunkur, similar to the above, is obtained in parts of the Jamna below the ordinary water level. Its more common form is in nodules, and in this form its occurrence is so general throughout alluvial soils in India wherever they exist that it were useless to attempt to indicate its geographical distribution in detail.

The better qualities of kunkur contain 70 per cent. of carbonate of lime; from this downwards the proportion constantly varies with the amount of clay or sand which is taken up.

Besides its usual employment for mortar, it is, when burnt and powdered without slaking, an excellent material for hydraulic cement. To this purpose of course only certain varieties are applicable.

VIII.—SANDSTONES.

Several of the recognised formations in India afford sandstones admirably suited for building, and some of them have from very early times been largely drawn upon for the supply of materials for this purpose.

Among these formations the great Vindhyan series stands pre-eminent. The difficulty in writing of the uses to which these rocks have been put is not in finding examples, but in selecting from the numerous ancient and modern buildings which crowd the cities of the North-Western Provinces and the Gangetic valley generally, and in which the stone-cutter's art often appears in its highest perfection.

The Lower Vindhyans,* consisting for the most part of shales and more or less flaggy limestones, and from the inaccessible position of the rocks in some of the principal places where they occur, as in the Són valley and Bandelkand, have not been worked to any great extent.

The Kaimúrs, however, have been worked extensively at Chunár, Mirzapúr, and Purtábpúr, as well as at minor intermediate points. The sandstones are in general fine-grained and of reddish-yellow or greyish-white colors. They occur in beds which are said to vary in thickness—at Purtábpúr and similarly elsewhere, from 6 inches to 8 feet. These beds often spread for long distances without any joints or fissures to break the continuity, in consequence of which very large blocks can and have been extracted for various purposes.

In the Riwa group, overlying the Kaimúrs, the sandstones are not so much used for building purposes.

"This is due partly to the beds being frequently coarse and harsh, and greatly subject to false bedding; partly to the fact that the Riwas do not occur much close to the Gangetic valley or to large cities. Some portions are, however, of superior quality, and supply all local wants."

Above the Riwas come the Lower Bandérs, which are described as being, for the most part, coarse, harsh, and gritty, and occurring only in thin beds.

* The following particulars are chiefly taken from Mr Mallet's Memoir

The Upper Bandérs, however, make up for the deficiencies of the underlying group by affording two varieties of excellent building stone, one dark-red, sometimes quite unspotted, sometimes streaked and dashed with yellowish-white spots.

The other is a yellowish-white, very fine grained rock, perfectly homogeneous both in texture and colour.

The latter is said to be, on the whole, the better building stone on account of its more uniform coloring and its being not so liable to disintegration from the effects of long continued exposure.

Probably the earliest use to which any of the rocks of the Vindhyan formation were put to was in the manufacture of stone implements, many of which, formed of the denser indurated varieties of sandstone, have been found in India.

So far as I have been able to ascertain there are no cave temples, or at least none of much note in the Vindhyan sandstones. But there are memorials of a very different class, many of which date from a period before which the idea of using stone in the construction of houses had not been entertained. At any rate, there are no buildings or remains of buildings which can with safety be regarded as belonging to so remote a period.

These memorials are the great monoliths or *lâts*, many of which bear the edicts of Asoka, the protector of the earliest Buddhists, and who reigned about 250 B. C. Besides these pillars he is said to have erected 84,000 Buddhist sanctuaries called stupas or topes.*

Some of these monoliths are of great size, and are generally polished throughout the portion intended to be exposed. They were surmounted by carved and ornamented capitals, upon which figures of lions or elephants were placed.

The polished portion of the shaft tapered uniformly from base to summit, and in every way these remarkable monuments testify to considerable skill in the stone-cutter's art. Still it would appear that this art was not made use of in the erection of buildings, and when the first stone temples† were excavated and adorned a century later, the stone architecture, as pointed out and described by Mr. Fergusson, was a "mere transcript of wooden forms," showing that at that time the art of using stone for these purposes was only being then first adopted, and that though the material was changed, the workmen continued to use the designs suited to wood. It was only gradually through several succeeding centuries that the forms and designs became suitable to the material.‡

It is considered by the best authorities that the palaces, temples, and buildings generally of those early times were mainly constructed of wood, as they are for the most part in Burma and Siam at the present day.

The resemblance between these monoliths and those of Egypt, some of which have been taken away into Europe, cannot fail to strike the attention. The connection is believed to be more than a mere apparent one, the discussion of which, however, belongs to the province of the Antiquary.

As these *lâts* afford the most striking evidence which can be given of the size of the stones which are obtainable from the Vindhyan sandstones and the durability of the material, I append the following enumeration of the principal of them which are known. The details are chiefly from General Cunningham's Archæological reports :—

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* Balfour's Cyclopædia, Article Asoka.

† Stone monuments, Fergusson, 1872, p. 456.

‡ It is right to add that this deduction of Mr. Fergusson is contested by Babu Rajendra Lal Mitter. See Jour. As. Soc., Bengal.

List of remarkable Monoliths in India.

Name.	Position.	Material.	Length. Observed.	Length. Estimated total.	Diameter. Upper.	Diameter. Lower.	Weight (estimated).	Age or period.
Bakra or Bhim Sen-ka lât ...	Beshrah, 27 miles east of Patna...	Polished sandstone ...	32′	36′-37′	38″·7	49″·8	50 tons ...	Unknown.
Navandgarh	Lauria, 15 miles north of Bettia...	"	32′ 9½″	...	26″·2	35″·5	18 tons (polished portion).	Asoka (About 250 to 200 B. C.)
Ara Raj		"	36′ 6″	...	37″·6	41″·8	34-40 tons ...	"
Firuz Shah's Pillar * ...	Delhi	"	...	42′ 7″	25″·3	38″·8	27 tons ...	"
" No. 2 † ...		......	32′ 8″	...	29″·5	35″·82	...	"
Bhim Sen-ka gada ...	Kosam, on the Jumna	......	28′	36′-40	29″·5	...	...	? "
Allahabad	... ...	......	...	42′	...	...	...	"
Kahaon	46 miles south-east of Goruckpúr	Coarse grey sandstone	24′ 3″	27′	...	...	...	84 A. D., or 219 A. D.
Bhutari	Between Benares and Ghazipúr ...	Reddish sandstone ...	15′ 5″	...	28″·85	...	...	? 100 A. D.

* Removed by Firuz Shah from its original site in district of Salora near Khizrabad, on the Jamna.

† Said to have been brought from Meerut.

Mr. Mallet mentions two large blocks which are found "about a mile south-east of Rupas near the quarry from which they were cut:" the dimensions of these suggest a near connection with those enumerated above. Not improbably they belong to the Asoka period. One is a circular column 34′ 6″ long, with upper and lower diameters of 2′ 8″ and 3′ 3″. The other is a parallelopiped 42′ 6″ long by 5′ 3″ × 3′ 8″ and 5′ 9″ × 4′ 1″, with an estimated weight of nearly 60 tons. The neighbouring villagers appear to know nothing of their history.

The quarries at Dehri on the Són are the most eastern of all those which have been opened in the Vindhyan rocks. At present they are largely worked in connection with the Són irrigation and canal projects. The stone is a compact whitish sandstone susceptible of artistic treatment, and, what is of more importance for the present purpose to which it is put, strong and durable.

The next point of importance where there are quarries is Chunár. The vicinity of the Ganges has, during a period of at least 2,000 years, afforded a ready means of transport for the excellent building stones which are obtained from the Kaimúr rocks at Chunár.

The East Indian Railway now affords an additional means of transport, but is, however, I believe, not very much used for the purpose, water carriage being so very much cheaper.

Benares, and other cities and towns of less note, both in ancient and modern times, have largely used Chunár sandstone. The ghâts at Benares, the palaces, the walls, the minarets, and many of the temples are built of this material. To Calcutta a certain quantity is brought for paving and tombstones, &c. The only stone church in Calcutta is St. John's, which is built of Chunár stone.

It has also been used to some extent in other buildings in Calcutta, but for paving purposes, as has elsewhere been shown, the so-called Burdwan stone has also been employed.

The next quarries to be mentioned are those of Mirzapúr, which, with those of Purtábpúr and Seorájpúr, have supplied Mirzapúr and Allahabad with material for the construction of their buildings, both ancient and modern. The stone for the Jamna bridge was, according to Mr. Mallet, obtained from some quarries a few miles up the river, whence it was brought down in boats.

From this the limits of the Vindhyan rocks sweep southwards in a great bay, and the next place where they have been worked to any large extent is in the neighbourhood of Gwalior, where they have been used in the construction of forts, temples, &c. It may be mentioned too that in the exposed faces of sandstone there are carved some figures of Titanic dimensions.

Although, as was remarked, the sandstones of the Riwa group are not generally used, still "in the neighbourhood of Hosungabad and also in the Sípri and Gwalior districts some thin red flags from $\frac{1}{2}$ to 1 inch thick are much used for roofing."

Perhaps the most important quarries in India are those in the upper Bandérs to the south of Bartpúr, at Fatipūr Sikri, and Rupás, which have furnished building materials since before the commencement of the Christian era to the cities of the adjoining plains. Portions of the Taj at Agra, Akber's palace at Fatipūr Sikri, the Jamma musjid at Delhi, and generally the grandest and the meanest buildings in Agra, Delhi, and Mutra (Mathura) have drawn upon these quarries for their materials.

To quote Mr. Mallet again: "The palace of the Rajah of Bartpúr at Deeg, which is regarded as one of the most beautiful edifices in India, testifies at once to the excellence of the stone employed and the skill attained by the stone-cutters of that district. Cupolas resting on slender shafts of 2 and 3 inches diameter, arches supported on strong, yet graceful pillars, windows formed of single slabs of stone perforated into the most elaborate tracing, meet one at every turn."

In conclusion, it may be mentioned that the sandstones both here and at Chunár have been largely used for telegraph posts; the facility with which some of the varieties split renders it possible to obtain posts 16' long of material which will resist white ants and the action of the weather.

Thus the ancient pillars of Vindhyan sandstone have been instrumental in annihilating time by preserving in an imperishable record fragments of the history of upwards of two

thousand years ago, while the posts of to-day have been subservient to the destruction of space, for it may be said that the telegraph which bears our messages from Calcutta to Peshawur over a distance of 1,500 miles in a few seconds of time practically overcomes space.

The preceding remarks refer only to the Vindhyan rocks, as exhibited in the great Vindhyan and associated ranges on the south of the Gangetic valley. In order to complete this notice, it will be necessary to allude to the occurrence of rocks believed to belong to the same geological period in other parts of the peninsula.

Between Sambalpúr and Raipúr in the valley of the Máhánadi, a series of sandstones, shales and limestones, considered to be contemporaneous with some of the Vindhyan series, occupy a considerable area. But in that wild part of the country there has as yet been no local demand for building stones.

Again, rocks referable to the Vindhyan series occur in the country to the south of Nágpúr, in the region about the confluence of the Weinganga and Warda rivers.

In the Karnúl district south of the Kistna there is another series of limestones, shales and quartzites which is considered to be referable to the Vindhyans.

Mr. King, in his description of these rocks and the underlying Kadapa formation, says: "There is no lack of good and easily wrought stone all over the district; but these can only become of value as they are locally required or as the means of communication are opened out over the district."*

For further examples of the uses to which these sandstones have been put in ancient times reference should be made to General Cunningham's Archæological Survey Reports.

Among the sandstones of the Dámúda series (the representative of the carboniferous period in India) there are several varieties which are suited for building purposes and which have already to a small extent been made use of.

Throughout the Dámúda valley where these rocks occur, they have been used in the construction of temples, some of which are of considerable antiquity. Among the finest examples three Jain temples at Barákar are deserving of particular notice, as exhibiting some rather elaborate carving which has stood well.

But still more ancient work in this material is to be seen in the caves of Sirguja and Cháng Bokhár, which bear inscriptions in the old *Pali* character, testifying to their extreme antiquity.

In recent times the sandstones at Barákar have been quarried largely for local use in the construction of the Barákar bridge and for various purposes in connection with the East Indian Railway. A considerable portion of the new High Court in Calcutta is also built of this material. Being readily accessible at the terminus of the Barákar branch of the railway, this rock will probably always be more or less used for purposes to which brick is not suited.

In Hazáribágh and Ránchi some of the sandstones of this series have been used to a small extent, and the flaggy beds of the underlying Tálchírs to a somewhat larger extent for paving the European barracks, &c.

References to these sandstones will be found in the numerous reports on coal-fields in the Memoirs and Records of the Geological Survey.

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The sandstones of the various groups included in the Máhádévá series have been largely used; the members of the lower groups are, however, in many cases either too friable or contain too much iron to be lasting when exposed to the atmosphere.

In the Bágra group, a sub-division of the Máhádévás, there are sandstones applicable to building purposes, and which have been used to some extent locally. The Tawa viaduct is built of these sandstones.

Some of the beds of sandstone in the Jabalpúr group yield an useful building material. A very dense indurated variety, which occurs in the station of Jabalpúr, has been quarried to a considerable extent for local purposes.* The viaduct over the Narbada below Jabalpúr furnishes the most important example of the applicability of the sandstones of this group to building purposes.

Close to Katák (Cuttack) there are some sandstones which Mr. Blanford considers to be younger than the Máhádévás, but the exact age of which is, from the absence of fossil remains, still uncertain. These sandstones were used in the construction of temples at Bobaneswar, and to some extent for various building purposes in Katák; but laterite and gneiss seem to have been more largely employed. Some ancient caves at Kundageree have been excavated in these rocks.†

The intertrappean rocks of the Rajmehal series, whose contained fossil plants present a markedly jurassic facies, consist of sandstones, flag beds, and shales. The two former are occasionally employed for local building purposes, but cannot be considered to be of much importance.

The compact sandstones of this series at Conjeveram and several other places offer, according to Mr. Foote, a very easily dressed and moderately durable building stone.

In reference to the jurassic rocks of Kach, Mr. Wynne says: "The finer grained slightly calcareous yellow sandstones of the lower jurassic group form tolerable building stone; and some of the close, hard silicious grit bands, though difficult to trim or dress fine, would afford a very lasting material for rough work."

Several other sandstones are locally used. Mr. Wynne gives a list of the different building stones used in Bhúj, as furnished to him by His Highness the Rao of Kach.

Rocks of this age are found in the Rajmehal Hills, U'tatúr (Ootatoor), and at various places on the east coast between Trichinopoli and the Godáveri and in Kach.‡

The Bágh beds, which belong, it is considered, to the cretaceous period, contain some good sandstones suited to building purposes. Mr. Blanford, in his report on Western India, says: "The massive sandstone of the Déva and those which occur throughout the country to the south of Allirájpúr and Bágh would furnish excellent material. The gritty calcareous bed at the top, where it is not too cherty, would be well adapted for construction and could be easily worked.§

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* Medlicott, Records, Geological Survey, V, p. 77.

† *References.*

Building materials of the district of Cuttack, Jour. As. Soc., Bengal, XI, p. 836.
Memoirs, Geological Survey, I, pp. 250 and 277.
Records, Geological Survey, V, p. 59.

‡ *References.*

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§ Blanford, Western India, Mem. Geol. Surv., India, VI, p. 380.

The rocks of the Sivâlik and Nâhan groups which represent the upper and middle tertiary period of Europe are generally too unconsolidated to form durable building stones. These rocks, as is well known, form the outer ranges of the Himalayas at various places from west to east.

Mr. Medlicott remarks: "Those stations, as Dagshai, Kasaoli, Subathu, Dhurmsala, which are built on the eocene groups of the Sub-Himalayan series, have an unfailing supply of good building material in the massive sandstone rocks. Among the older rocks there is no stone fit for anything but that for which rough rubble may be used. There are several examples of native architecture along the border of the plains for which an excellent building stone was obtained from rocks of the Sivâlik group, but it must have been found in detached blocks and discontinuous bands, the mass of the rock being quite unfit for the purpose. Stone fit for ornamental or monumental purposes might be found among the thick-bedded, hard limestones of the Krol group."*

QUARTZITES.

The gradation from the loosest and most granular sandstone to the most intensely vitrified quartzite is so complete that it is impossible to draw a sharp line of demarcation between them. I therefore place the quartzites with the sandstones in this enumeration. Were the arrangement a purely geological one, a large portion of them would have to be classed with the schistose or gneissic rocks.

If we except those varieties of the Vindhyan and Karnúl sandstones which are sometimes called quartzites, the use of rocks coming under this denomination has been very inconsiderable. Indeed the only instance known of a quartzite being regularly quarried is in the Susinia Hill in Mánbhúm. The works there were carried on for some years by the Burdwan Paving Stone Company, and large quantities of the stone have been used in Calcutta for pavings, copings, and other similar purposes. There are several varieties of this material found; in some there is a large proportion of felspar, when it should be called granulit rather than quartzite.

Although these rocks have been so little used, the Bijaur or submetamorphic series, in many parts of the country, afford quartzites suitable for building purposes; wherever these occur in the vicinity of Vindhyan sandstones, the latter will naturally be preferred, as they are in most instances much more easily worked. The vitreous fracture of many quartzites is in fact a bar to their employment where much finish is required.

IX.—LATERITE.

The term laterite has been applied generically to a group of rocks which play an important part in the superficial geology of India. The common character which persists throughout all the varieties of laterite is the possession of a ferruginous element which is in the form of brown hydrated peroxide on the surface, sometimes as the black magnetic ore inside. The reddish-brown appearance, due to the presence of the peroxide, explains the origin of the name (*later*, a brick) which was, I believe, first conferred upon it by Dr. Buchanan.

The various forms in which laterite occurs are due to differences of composition and differences of structure. The combinations of these two qualities produce almost infinite varieties. The principal structural varieties are either nodular or cellular, the former being the younger, and it is supposed, in a measure, derived from the latter. The varieties in composition vary much in the quantity of the peroxide which they contain and in the character of the other materials. Both classes pass off into mere detrital laterite, to the ferruginous element in which they have no doubt mainly contributed.

* Medlicott, Mem. Geol. Surv., India, III, p. 175

This is not the place for going into details or enumerating the various theories which have been suggested to account for the origin of this most singular deposit. It may be mentioned, however, that no theory accounts satisfactorily for the sources whence the large amount of iron can have been derived.

The distribution of laterite in India is widespread throughout the Peninsula, Ceylon, and in Burma. It occurs not only as a costal deposit underneath the Eastern and Western Ghâts, but also in many parts of the interior, not unfrequently capping lofty hills and plateaus to a depth of several hundred feet, often producing the dead level surfaces which constitute a striking feature in Indian scenery. Although perhaps it shows its finest development on or in the vicinity of trappean rocks, it occurs resting on rocks of all periods, occasionally far removed from any exposure of trap. It has not been observed, I believe, in any part of the Himalayas.

As a building stone, though it can hardly be called ornamental, it possesses some qualities which render it acceptable in the eyes of the natives; it is easily worked, hardens on exposure, and wears well. In the costal districts many temples, some of considerable antiquity, are built of laterite and appear to have stood well. In the Rajmehal Hills there is a small fort built of neatly cut blocks of laterite without mortar. These blocks have retained their original sharp edges.

In Midnapúr and Orissa slabs of from 4 to 5 feet long are extracted by cutting a groove round the slab above and another underneath, a few wedges are then driven into the latter, and the slab splits off. This or a nearly similar process is used for the extraction of blocks of laterite in all parts of the country where it is worked by natives.

Mr. King, in his Geology of Trichinopoli, says: "Where of poor quality, the laterite soon crumbles away when exposed to the influences of weather and moisture, as may be seen in the basement of many of the houses in the Fort of Tanjore. The laterite has there weathered away, leaving the walls perfectly honeycombed, and the layers of mortar, which are more durable, standing out as a regular net-work." In a note Mr. Foote adds: "The laterite in this case was in all probability badly selected, for in all my subsequent observations of this stone as a building material, it would appear that continued exposure to atmospheric influences, or wet, as in the case of tanks or bowries, only tends to improve the stone. Most of the religious edifices and tanks constructed of this stone show the lines and angles of the carvings as sharply as though fresh from the builder's hands."

Mr. H. Blanford also remarks: "At Andanapet I noticed some carved blocks forming part of an old and ruined pagoda the mouldings of which were as perfect as when first cut. Owing to its porous structure, however, laterite is but little fitted for fine sculpture."

Laterite has been largely used in the works in connection with the irrigation operations in Orissa. The anicut on the Kossai at Midnapúr has been altogether built of this material. The stone for these purposes has, I believe, given the engineers much satisfaction.

The Vellour anicut at Chetia-tope near Bhowagiri in the Trichinopoli district is partly built of laterite.

Dr. Balfour gives the Arcade Inquisition at Goa, St. Mary's Church, Madras, and the old fortress at Malacca, as examples of its use in the construction of buildings by Europeans.*

* *References.*

Midnapúr, Orissa, Mem Geol. Surv., India, I, p. 277.
W. T Blanford, on Laterite, Mem. Geol. Surv., India, I, p. 280.
H. Blanford, Southern India, Mem. Geol. Surv., India, IV, p. 206
King, Trichinopoli, Mem. Geol. Surv., India, IV, p. 372.
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X.—SLATES.

For building purposes, more particularly for roofing, slates have not been much used in India, except in some of the stations of the North-West Himalayas. This is probably due to two causes, the first and principal being that in the oriental style of flat-roofed architecture which is generally adopted for British buildings in India, slates could be only partially employed, and in the alluvial districts their place is amply filled by tiles.

Secondly, most of the slates known to occur in India, are either non-cleavable, or, if cleavable, retain also their laminated faces. The laminated slates are difficult to work into sufficiently thin layers, and are not much used, as an undue amount of timbering becomes requisite to support the weight of slates of this character.

At Dalhousie there are some large quarries in which there are slates and schists of various qualities. The best are said to be much more schistose than Welsh slates, still they are readily fissile, can be easily dressed, and can be obtained of considerable size. The fissile plains are in this instance parallel or nearly so to those of lamination.

The slates in use at Simla* are, according to Mr. Medlicott, distinctly laminated, and in every way inferior to those obtained along the flanks of the Dháoladhár, and which are used at Dalhousie and Dhurmsala.

Slates, the qualities of which are not so well known, are also obtained at Ferozpúr, Páli, Chimnawar, and Sonah, all in Gurgaon, and at Attock, Abbotabad, and Spiti.

At Chitéli, in Kumaon, occurs a slate which it was proposed to employ for roofing purposes at Ranikhet and other places. Mr. Hughes, comparing this slate with the Welsh standard, writes: "It differs from the latter in splitting along the lines of lamination instead of the planes of cleavage. It is coarser in texture, more silicious (sandy), heavier, and has a duller ring on being struck." The supply is ample for all possible requirements, and slabs of a foot square, ½ of an inch thick, can be obtained easily.

In the submetamorphic rocks (Bijaur series) of Chota Nágpúr slates not uncommonly occur. In these the fissile planes are for the most part those of lamination. In Mánbhúm I met with a bed, however, which had most distinct cleavage structure, but there was also a tendency to split along the layers of lamination; thus, this rock breaks up into regular prisms at the surface, but it is not impossible that a good slate might be obtained, as the material is compact and dense.

In Chaibassa the school-boys have only to run down to the stream near the town to obtain a new slate for doing their sums on.

In the Karakpúr Hills, near Monghir, slates have been extracted.

The demand for slate is so small in Calcutta that I do not think it probable that these slates will ever be quarried to any large extent.

In the Champanir beds between Soorajpúr and Jumbooghora, north-east of Baroda, there are some slates which, as far as can be judged from their appearance at the surface, are considered promising by Mr. Blanford.

In the Bijaur series near Bágh there are also slates which are not so fine grained as the preceding, but some of which might perhaps answer for roofing purposes.

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* Some of the slates which have been used at Simla for roofing temples are said to have lasted for hundreds of years.

Clay-slates occur both in the Kadapa and Karnúl formations in Madras; but though thin slabs can be obtained, they are not suited for roofing purposes, and where harder and more durable stone is obtainable their employment for flagging is not recommended.

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SECOND NOTE ON THE MATERIALS FOR IRON MANUFACTURE IN THE RÁNIGANJ COAL-FIELD, *by* THEODORE W. H. HUGHES, A. R. S. M., F. G. S., *Geological Survey of India.*

In continuation of my former paper* on the raw materials for iron smelting in the Rániganj field, I have a few analyses of iron ore and kunkur to record which will afford a more complete series for computing their values than already exists.

Iron-ore.—The percentage of iron in several different samples of ore from various spots in the Rániganj field has been given in the Memoirs of the Geological Survey,† but the impurities were not separately estimated. In the following analyses the amount of alumina, lime, phosphoric acid, and insoluble residue, besides the iron, is indicated; and a useful comparison can be instituted between the Rániganj ores and those of other countries. All the samples are derived from the iron-stone measures, known geologically as the iron-stone shales group, and they were collected entirely in the western portion of the field:—

	Bagúnia No. 1.	Bagúnia No. 2.	Boldih.	Chalbalpúr.	Kúlti.	Malákolá.	Sibpúr.	REMARKS.
Insoluble	13·6	10·6	20·4	14·8	19·6	18·8	21·2	(a). A little magnesia and sulphuric acid occur in the Chalbalpúr, Chinákúri, and Malákolá ores. Being small, it was not quantitatively determined.
(Silica)	(11·6)	(8·6)	(16·8)	(12·1)	(16·4)	(16·2)	(17·)	
Sesquioxide of iron ...	65·44	53·2	52·28	66·45	60·4	62·92	43·82	
Protoxide of iron ...	...	13·48	1·08	...	...	...	8·92	
Alumina	6·25	4·07	5·89	4·7	5·8	3·91	5·17	
Lime...	·8	1·0	4·03	2·24	2·9	2·88	3·36	
Magnesia	·7	·85	1·8	*a*	·6	*a*	*a*	
Phosphoric acid	·71	·57	1·43	2·05	2·2	2·57	2·3	
Sulphuric acid	...	·55	...	*a*	...	*a*	*a*	
Loss on ignition ...	13·5	16·0	13·2	9·6	9·3	10·3	14·4	
TOTAL ...	101·0	100·32	100·15	98·84	100·7	101·28	99·17	
Metallic iron ...	45·80	47·72	37·43	46·5	42·28	44·03	37·60	

* Records, Geological Survey of India, 1874, Vol. VII, Pt. I, p. 20.

† Memoirs, Geological Survey of India, 1860, Vol. III, Art. 1, p. 194.

Phosphorus.—An abstract of the phosphorus contained in these samples shows that the minimum quantity is ·23 per cent., while the maximum is 1·12 per cent. :—

Bagúnia	·31
Boldih	·62
Chalbalpúr	·89
Kúlti	·95
Sibpúr	1·04
Maláskolá	1·12

These results indicate that much of the ironstone might be employed for the production of iron, but that some of them are bad.

It is possible that the quality of certain beds may be regular or nearly so, in respect to the amount of phosphorus they contain, and that by selection we may avoid the use of such bands as may be unsuitable. This feature must be determined before a final opinion can be expressed on the value of the ironstones.

Proportion of iron.—The proportion of iron is much larger than that contained in the bulk of ores employed in England; and some specimens are much richer than is indicated by the foregoing analyses.*

Kunkur.—These samples were examined by Mr. Tween, showing the amount of oxide of iron, alumina, insoluble residue, water and organic matter contained in them. The minimum quantity of carbonate of lime is 54 per cent.—

	Barmúrí.	Rámnagar.	Sánktoria.
Insoluble	40·6	30·4	27·2
(Silica)	(32·8)	(23·0)	(19·4)
Oxide of iron and alumina	2·7	1·9	2·0
Carbonate of lime	54·0	65·4	66·3
Water and organic matter	2·7	2·3	4·5

Other samples of kunkur from the above localities gave of carbonate of lime—

Barmúrí	61·1	per cent.
Rámnagar	64·98	„
Sánktoria	66·12	„

The finest specimens were since furnished by Mr. Hynd, of Báséрá. They contained as much as 79·5 per cent. A few analyses (in subjoined table) placed at my disposal by Mr. Dejoux show a range from 56·94 to 78·50 per cent. of carbonate of lime, giving an average result for the entire series of analyses of about 65 per cent. With this proportion of carbonate of lime, kunkur will be quite capable of acting as an efficient flux.

	Rániganj.	Ránigánj.	Ránigánj.	Barrákar.	Bhiokúnd.
Carbonate of lime	72·0	56·94	66·50	66·20	78·50
Carbonate of magnesia	1·30	1·72	·20	1·50	2·00
Oxide of iron	·70	1·67	3·20	2·80	2·00
Clay	22·0	30·0	27·60	22·00	10·50
Sand (free)	2·0	9·67	2·50	7·50	7·00
TOTAL ...	100·00	100·00	100·00	100·00	100·00

* A sample from the Madápúr property of the Ránigánj Coal Association yielded as much as 52·45 per cent. of iron, and laterite from the same locality gave 25·38 per cent., which is above the average for that form of ore.

Limestone.—Besides kunkur there is some impure rock-limestone near the village of Páhárpúr at the base of Panchet Hill. It is a well known bed, and is marked on the revised map of the Rániganj field. It contains 56·43 per cent. of carbonate of lime, and varies in thickness from 12 to 15 feet. A large quantity of stone might be obtained from it, but it possesses the disadvantage of dipping at a high angle.

Calcareous nodules.—There is, in addition to kunkur and rock-limestone, another source of flux, and that is the calcareous nodules in the clay beds of the Panchet series. The average proportion of carbonate of lime was found to be 66·8 per cent. The importance of this supply is quite subordinate to the kunkur, but it is well to bear it in mind.

Calcareous concretions also occur in the Tálchír series.

Limestone beyond the field.—In reference to limestone beyond the field, I have no additional information to record regarding the stone discovered by my colleague Mr. Mallet; but I have had an opportunity of inspecting a small quantity of limestone brought from the south side of the Damúdá near Rániganj. It looks extremely pure, and if it occurs in anything like quantity, it would be of great value.* I scarcely anticipate, however, that it will be found in abundance, and the kunkur will, in the event of any attempt to establish large iron works, probably be the flux on which to rely.

Use of kunkur in Bírbhúm iron works, 1860.—Kunkur was successfully employed in the Bírbhúm iron works, and Mr. Blanford, when reporting upon them in 1860, records as a fact that Mr. Casperz, the manager, found it advantageous to partially burn the kunkur and then to slake it, in order to separate the more impure external parts.

This process could only be advantageously applied to the more regularly concretionary varieties of kunkur, showing centrical concentration, for the ordinary form of this rock is without any distinctive purer core.

Relative quantity of ore and kunkur.—I stated in my former paper that equal quantities of ore and kunkur would be required for the production of iron in a blast furnace. In the Bírbhúm works, a less proportion of kunkur was found to be sufficient, only 3 of kunkur to 7 of ore being necessary. Charcoal, however, was the fuel then employed, whereas in my experiments, coke containing as much as 30 and 40 per cent. of ash was used, and the ore was not quite so clean. With better coke, and an ore with an average of 42 per cent. of iron, the amount of kunkur requisite would be less. In estimates of the cost of manufacture, however, it is as well to be on the safe side, and equal quantities ought to be allowed for.

Malleable iron.—For the production of malleable iron, the direct process, which, I am indirectly informed, has been quite recently perfected by Dr. Siemens, greatly improves the prospect of the undertaking in India, for the impure as well as for the purer ores. One of the chief objections made to this process by iron-masters in England, that a greater proportion of the iron passes into the slag than occurs in the present method of manufacture, does not apply to the case in India, where a saving of materials is quite a secondary consideration to that of a saving in skilled labour.

The advantage claimed for this process, of not bringing the phosphorus into combination with the iron, removes one of the most serious impediments to the development of the great advantages for iron manufacture otherwise possessed by the Ránigan] coal-field.

* Since writing the above, I have visited the locality whence the limestone was taken. It occurs as nearly pure calc-spar in small veins, striking N. and S., through a decomposed bed of gneiss. It will pay for extraction for special purposes, but cannot be looked to as a source of flux.

MANGANESE ORE IN THE WARDHA COAL-FIELD.

In connection with the question of iron-manufacture in India, it will be of interest to notice a discovery I made this year, within the limits of the Wardha coal-field, of a deposit of manganese ore, which is at present an ingredient of great service in the process for converting iron into steel, although its prime function in that process, and the presence of a certain proportion of manganese in the best steel, are questions still under discussion.

In 1869 I drew attention, in the manuscript report of my season's work, to the occurrence of manganiferous sandstone in the Kámthi series, but the proportion of manganese to the other constituents of the sandstone was altogether too small to render my discovery anything more than merely interesting. This year I was fortunate enough to meet with a much more available source of manganese, and it is this source which I wish to draw attention to.

The ore occurs in botryoidal masses in the red clays of the Kámthi series around Malágarh Hill. These concretionary lumps as usual contain much foreign matter, but the proportion of oxide of manganese is considerable. An analysis by Mr. Tween gave:

Manganese ore—

Loss on heating	8·5
Oxide of manganese	44·6
Iron and alumina	6·8
Sand and clay	40·1
TOTAL ...	100·0

The physical characters are those of psilomelane, which is a proto-peroxide of manganese; hard, having a bluish black colour, submetallic lustre, and a brownish black streak.

Of the ores of manganese this is about the most abundant. It is closely allied to pyrolusite, and by some mineralogists is considered to be only an impure variety of it.

I did not attempt to estimate the probable quantity procurable from the beds in which this ore occurs, as I wished before tracing it out closely to have its value determined analytically. I remember, however, being impressed with the idea that there was a large amount of it, of more and less purity than the sample I sent to our Museum.

None of our Indian iron-ores are known to contain more than a trace of manganese, and the independent ores of this metal seem to be somewhat scarce.

In the Panjáb it is said to come from Jammú, which may mean anywhere within the extensive Himalayan territory of the Máháráj of Kashmír.

In Madras it is said to occur near Vizianágram, in Karnúl, Maisúr, and the Nilghiris.

In Barmá, it has been reported upon by our own officers and others.

In Bombay an earthy mixture of iron and manganese oxides, occurring as a dark brown powder in magnesian limestone, was found this year by my colleague Mr. Foote, at Bhimgarh in the Belgaum district. Its composition is—

Water and organic matter	14·6
Oxide of iron and a little alumina	22·0
Binoxide of manganese	20·0
Insoluble	44·8
	101·4

The consumption of manganese ore has hitherto been very unimportant in India; but if the extensive plans now under consideration for the conversion of the pure iron-ores of Lohárá be ever carried out, we may expect a considerable demand for manganese.

THEODORE W. H. HUGHES.

Calcutta, 1st July 1874.

DONATIONS TO MUSEUM.

MAY 21ST.—Part of lower jaw of Mastodon, from the bed of the Chumbul, Dholepore. Presented by D. A. DUNN, ESQ., C. E.

Specimen of the rock from bottom of a deep well (550 feet) at Bikaneer. Presented by COLONEL MCMAHON, Hissar.

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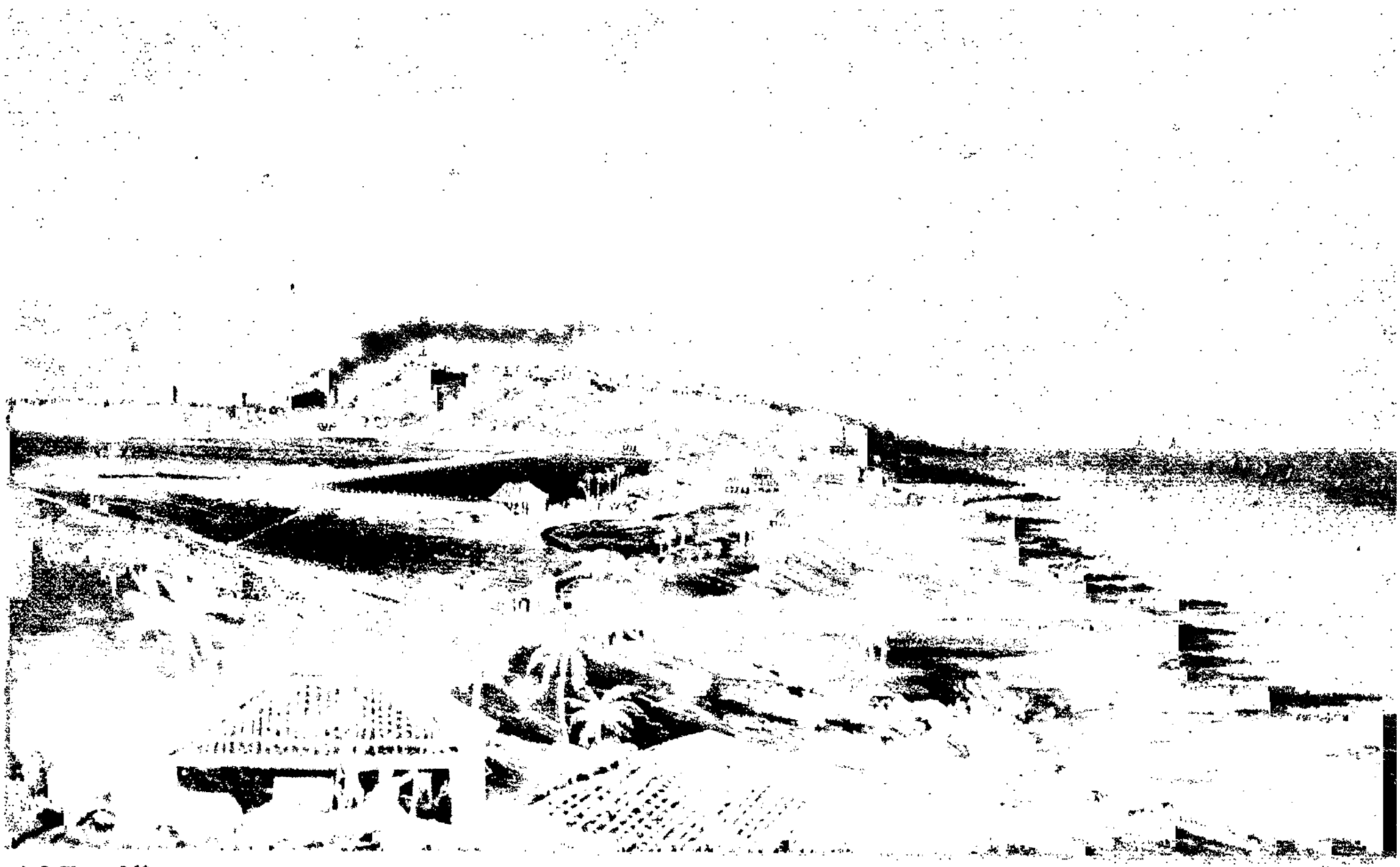

A. B Wynne delᵗ

H. L. Frazer Li

BOMBAY ISLAND.

Malabar ridge seen from Wurlee Hill.

The labours of the Geological Survey of India were extended to the Presidency of Bombay about three years since, and a small party formed there, and placed under the charge of Wm. T. Blanford, Esq., F. G. S.

The following brief description of the structure of the Island of Bombay, prepared under Mr. Blanford's direction, is the first of a series relating to Western India, which will appear from time to time.

THOMAS OLDHAM,
Superintendent of the Geological Survey of India.

Calcutta, April 1866.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

On the Geology of the Island of BOMBAY, *by* A. B. WYNNE, F. G. S., &C.,
Geological Survey of India.

CONTENTS.

1.—INTRODUCTION.

The geological structure of Bombay Island, although closely allied to that of the neighbouring coast and other portions of Western India, presents local differences of considerable interest which have already attracted the attention of members of the Bombay Scientific Societies and of other observers.

Previous observers.

Several papers have appeared as the results of their investigations,* the writers having left little to be added to the details already collected save what can be gathered from excavations subsequently made. As, however, all these

* The two most comprehensive of these papers will be found reprinted, and the rest alluded to, in "Papers on the Geology of Western India", edited by Dr. Carter for Government, and published in Bombay, in 1857.

papers contain accurate descriptions of the details rather than correct conclusions with regard to the arrangement of the rocks and the structural geology of the district, it will be well before proceeding further to notice briefly each writer's views.

Dr. Thompson, 1836.

The earliest of these papers to which access could be obtained is a "Sketch of the geology of the Bombay Islands," by Robt. D. Thompson, M. D., (Madras Journal of Literature and Science, 1836, Vol. V, page 159.)

The author commences by briefly describing the meteorology and physical geography of the islands around Bombay; then proceeds to enumerate the varieties of rocks found on them, and the simple minerals occurring in the same rocks. He next furnishes a separate sketch of the geology of each island, and concludes with general observations upon the configuration of the western coast. In the description of Bombay Island some of the kinds of rock occurring in different localities are noticed, but very little is said of their relations to each other; and the author classes the whole broadly as claystone-porphyry, and amygdaloid, with basalt appearing in places, as on Malabar Hill, each rock admitting of considerable variation in the amounts of the constituent minerals. At page 165 he mentions the approximate similarity of the hard close-grained rock of Baboola Tank to "greenstone, as it appears sometimes in Scotland with the aspect of an aqueous deposit." The paper is somewhat discursive, and many matters not directly connected with Geology are discussed.

Dr. Lush, 1836.

In a paper entitled 'Geological notes on the northern Conkan, &c.,' (published in the Journal of the Asiatic Society of Bengal; December 1836, Vol. V., p. 761), Doctor C. Lush gives a passing notice of Bombay. He speaks of "horizontal strata of sandstone containing shells" obviously the 'littoral concrete' of later writers and justly concludes that these beds are above the trap rocks.

G. T. Clark, 1847.

Next in order of time is a paper by G. T. Clark, Esq., C. E., (Quarterly Journal of the Geological Society, London, Vol. III, page 221, January, 1847). The opening paragraph contains the nearest approach to the true state of the case to be found in any of the papers which we have seen, so far as structural arrangement is concerned. It is as follows:—"The Island of Bombay is composed of five or six bands of trap rock, chiefly greenstone and amygdaloid, conformably dipping west at about 10° or 15°, and separated by beds that have the appearance of being of sedimentary origin, though there is no actual proof of the fact." Since this was written abundant evidence to prove the intervening beds to be of sedimentary origin has been found. Of their appearance or exposure at that time of course nothing can be stated here, but it seems strange that so accurate an observer, as the first part of this paragraph proves Mr. Clark to have been, should have made the reservation contained in the concluding lines.

The chief portion of this paper refers not to the Island of Bombay itself, but to the Konkan and Deccan, parts of the main-land at considerable distances from Bombay.

Dr. Buist, 1851.

After these papers come several communications to the Bombay Geographical Society, the Bengal Asiatic Society, and the British Association for the advancement of Science,—the results of Dr. Buist's exertions,—all which appear to have been subsequently combined in his paper "on the geology of the Island of Bombay." (Transactions, Bombay Geographical Society, 1851, Vol. X, page 167.)

In this paper the position and physical features of the Island; the various kinds of rocks, clays, soils, the supplies of water, and the evidences of elevation and depression in recent times, are treated of: the author confining himself chiefly to descriptions of observed facts, and leaving his

conclusions with regard to the geological sequence of the different rocks in a great degree to be inferred indirectly from what he states.

It would appear from the manner in which the 'sedimentary beds' of Mr. Clark are described,—their being called 'fresh-water beds' and stated to alternate with the traps,—*that the author agreed with Mr. Clark as to the general structure of the Island; but this is not prominently put forward. Each side of the Island is separately described in detail, and the centre has a section devoted to itself. We do not find it stated that the same rocks occur at both sides of the Island. The traps are mentioned as basalt, greenstone, porphyry, amygdaloid, and trap-tuffa; the clays and other superficial deposits are treated of at length, and all the rocks of the Island are minutely described. The evidence regarding recent upheaval and depression of the district is considered, (at least one recent elevation of Bombay being proved,) and lastly, there are sections upon 'supplies of water,' and upon 'papers upon the geology of Bombay' which had previously appeared.

As to matters of fact and detail this is a valuable paper, there being but few points in it to which objection can be made, while the amount of information it conveys is very large.

At about the same period, although bearing a somewhat later date,

Dr. H. J. Carter, 1862.

we have Dr. Carter's paper ('Geology of the Island of Bombay, with a geological map and plates.' Journal Bomb. Bran. Royal Asiatic Society, July 1862, Vol. IV., page 161: read December 1850.) This, although in a different way, is even a more elaborate and exhaustive treatise than that of Dr. Buist. The details are somewhat more generalized as regards localities, while the composition of the rocks is more minutely treated of.

* Dr. Buist is unquestionably correct in this opinion. He mentions(page 189, Geological Papers on Western India,) his conviction that there are at least six deposits of sedimentary matter cropping out between Lovegrove and Sewree, (a distance of five miles).

And a large portion of the paper is occupied by descriptions of the fossils found in the "fresh-water beds."

The paper opens with a summary containing assertions sought to be established throughout regarding the arrangement and sub-division into periods of the various rocks to be found in the Island. According to the author these sub-divisions are four; the first representing whatever the base of the Island rests upon; the second, including the fresh-water formation, is referred to as an accumulation deposited by a lake or river horizontally all over the Island of Bombay, afterwards covered over by a sheet of basalt, and later still intruded into and broken up by other igneous rocks. These igneous rocks form the author's third period, and they are again sub-divided into four 'effusions,' each of which is traced in its various exposures throughout the Island. All igneous rocks seen are assigned to one or other of these 'effusions.' The fourth period is represented by the 'marine formation,' consisting of recent deposits of clay, calcareous 'littoral concrete,' &c.

Nomenclature adopted by Dr. Carter.

After this summary the author enters upon a detailed description of the geography and geology of the Island, adopting in the lithological portions of his paper the classification of M. Alexandre Brongniart, as given in the *Dictionnaire des Sciences Naturelles*, under the article *Roches*.

The rocks, with the exception of the fresh-water strata, are all stated to be volcanic, belonging to the trappean system, and the names trappite,* basalt, trappito-basalt, aphanite, spilite, amygdaloid, and volcanic breccia, are used as distinctive terms.

The trappite is stated to occur on both sides of the Island, to have once in all probability extended across it, and to be traceable throughout its whole length except at the northern end. It is looked upon

* In the first edition of Dr. Carter's paper the trappite was called diorite.

as one mass whose upper part is more crystalline and tough than that beneath; 'its structure sometimes almost assuming the form of the Bombay basalt,' and it is supposed to have overflowed a plain formed by the fresh water strata over the whole Island. The basalt of Bombay is included within the same period as this trappite under the name of 'trappito-basaltic tract,' and is considered part of one and the same formation.

As next in succession below this trappite the fresh-water beds are then considered, and the author, viewing them as one horizontally extended and undivided group, having, however, a slight anticlinal curvature beneath Malabar Hill, gives a minutely detailed description of their mode of occurrence at the sluices (Lovegrove), where, he says, they are least disturbed and best seen. In connexion with this portion of the paper is the very full description of the fossils found in these beds by Dr. Leith and by the author.

Following the description of the fresh-water beds is that of the 'second volcanic effusion,' which is stated to have flowed in between, and to have broken up, the aqueous strata, but it is not supposed to have penetrated the overlying trappito-basalt. It is said to appear in many parts of the Island and to assume a variety of forms, from one hardly recognisable as different from the trappite, through various kinds of amygdaloid, aphanite, spilite, white trap, vesicular rock containing geodes of quartz crystals, to massive varieties which have lost their crystalline appearance and have assumed a compact structure 'opaque, white, and greasy to the nail.' It is looked upon as the agent by which the ridges of the island have been elevated, and the two foregoing subdivisions disturbed and displaced.

The third volcanic effusion is then described as having broken up and converted the fresh-water strata and other rocks into a volcanic breccia. It also is stated to have many varieties, passing from white powdery

aphanite and light colored soft earthy or sandy (? decomposed) rock to a hard black jaspideous or chertified variety. It is frequently red or mottled, and large fragments of the fresh-water beds are said to be enclosed in it. This third effusion is stated to be penetrated by dykes of another and newer rock of the same kind belonging to a fourth effusion. In connection with this subject the author gives his opinion that the third effusion is contemporaneous with the laterite formations and in some places identical with them, and to establish this, he reviews the descriptions of laterite given by Dr. Buchanan, Dr. Christie, Mr. B. Babington, Dr. Voysey, Mr. Cole, Mr. Coulthard, Captain Newbold, and Dr. McClelland, comparing these with his own observations, stating the difference between the breccia of this 'effusion' and genuine laterite, and arguing that the latter must extend further north than was previously supposed.

The author then passes to the consideration of the newer formations, describing the clay, shell-concrete, and blown sand of the central and littoral portions of the Island, and after some practical observations upon the building stone, lime, sand, wells, and coaly portions of the fossiliferous strata, concludes his paper with a list of rock specimens, minerals, and fossils presented to the Bombay Asiatic Society by himself and Dr. Leith and an explanation of the map and plates to illustrate his paper. From the above sketch it will be seen that this is a very comprehensive and elaborate paper, in which strong conclusions are arrived at and copious details given.

Many of the author's observations are supported by an examination of the ground, and although most of his details are accurate and have been collected with much care, certain of his deductions, and particularly those bearing upon the generalized view of the geology of the Island, appear to be untenable.

At the outset the fact, that the Island is formed of a series of beds dipping to the west, as observed by Mr. G. Clark, seems to have

entirely escaped Dr. Carter's attention, although he notices one of the consequences of this structure in the shape of the ridges and in their scarped sides being to the east, while all their longer slopes are presented to the west. Again, although the rocks are superimposed upon each other almost in the order in which he places them, we have not been able to discover any evidence for their sub-division into his four groups, nor yet for any of these having been erupted *within* the limits of the island, and consequently we are unable to admit the conclusion that the hills of this district have been elevated by the force of *local* intrusions of igneous rock beneath them. Neither can we agree with the statement that the fresh-water strata, or shale series, existed as but one continuous horizontal and undivided group forming a plain, resting upon which a sheet of trap stretched across the Island from side to side.

As the strata of which Bombay Island is mainly composed all incline to the west, and other rocks of the series intervene between the bands of shale, a series of step-faults along the strike, causing repetitions of the same beds at the surface where the shales are now found, would be necessary to establish Dr. Carter's conclusion; but there is no visible evidence to warrant the supposition that faults of the kind exist, or that the various shale exposures are different portions of a single group.

In the mineralogical and lithological parts of the paper certain minute distinctions are made between varieties of the rocks; while more striking varieties which are even prominently mentioned have been included together in classifying or in tracing out one or other of the 'effusions:' these variations being attributed to local causes in connexion with each irruption supposed to have taken place within the area now occupied by the Island of Bombay.

Although the author's general deductions seem to have been vitiated by his having overlooked the true stratigraphical relations of the rocks, the paper is still valuable as a record of geological observations.

Having thus briefly alluded to such publications treating of the geology of Bombay as could be consulted, and having expressed our dissent from some of Dr. Carter's deductions, we shall proceed to explain the geological facts as represented upon the accompanying map, Plate I and Sections, Plate II; with less detail, however, than would have been necessary had not the authors of the papers noticed above already treated the subject as fully as they have done.

2.—General Description of the Ground.

The Island of Bombay, upon which the city of the same name is situated, is one of a picturesque group on the western coast of Hindoostan crossed by the 19th parallel of north latitude, which passes over the Island of Bombay. This group, including the larger and more lofty Islands of Salsette and Trombay, divided by but narrow tidal creeks from each other and from the shore, is so situated as to embrace between it and the main land the beautiful and spacious harbour, which has a width varying from five to seven miles. The conspicuous Island of Elephanta, famous for its cave temples, lies entirely within the harbour; and many other detached islets complete the group.

Several of the neighbouring Islands have higher elevations than that of Bombay, within which only small ridges and chains of hills varying in height from 85 to 180 feet* occur. The eminences around Bombay, however, command splendid views of the extensive harbour, with its hilly Islands backed by the long mural ranges and here and there peculiarly pinnacled summits of the Ghâts, while the adjacent Islands, with portions of the main land separated by narrow belts of water, present beautiful examples of rugged and rocky scenery frequently covered with jungle and brushwood down to the water's edge, and there bordered by mangrove bushes and lofty palms.

United to Bombay by causeways are the two small Colaba Islands to the south, and other causeways connect Bombay with Salsette to the North. Including the former the Island of Bombay extends in a direction a little east of north and west of south to a length of about 11½ miles on the landward side, 6 on the western or seaward side, and has a width of about 3 miles at the broadest part, containing a calculated area of a little more than 16 square miles.†

* These heights are taken from "Papers on the Geology of Western India" before referred to.

† These distances are from the Atlas Sheet No. 25; the area from information kindly afforded by Dr. Leith.

Description of the ground in connection with its geology.—Such features as the ground presents are (like those of most other places) the results of denudation; they consist of the previously mentioned ridges extending along and determining the direction of the Island; the best defined is that of Malabar Hill, forming the Island's "western sea-wall," projecting to the south as Malabar Point, broken through completely midway, at the Vallade, and running into the sea again at its northern end, where it terminates in Wurlee Point. Its greatest height is stated to be 180 feet.—*(Dr. Carter.)*

Hill ridges.

The other ridges or chains of hills stretch along the eastern side of the Island, leaving its centre entirely occupied by a level plain; they commence at Nowrojee Hill close to the city, and extend northwards in parallel directions, but otherwise irregularly, with heights of 160 feet and less, by Mazagaon, Chinchpooglee, and Antop Hill, towards Sion, where their resemblance to ridges ceases, and they become merely a cluster of hills. Although not possessing any very conspicuous physical features, the hills rise sharply upon one side, and with a somewhat more gentle slope upon the other, from the muddy shores at the Island's northern extremity and eastern side, or from the level flat which stretches through it from end to end, gaining by contrast much of what they want in elevation. The longer and more gentle slopes of all the ridges are presented to the west, while their steeper sides and cliffs face to the east; a character well seen in Malabar Hill. It may be observed also that each of these long slopes is mainly formed of one kind of rock, and on closer examination planes of stratification will be found coinciding in a general way with the western surfaces of the hills, that is,

Westerly dip.

having a more or less westerly dip. Further, upon crossing the Island and these planes of stratification at right angles, we find that varieties occur amongst the

rocks; the basalt of Malabar ridge differs from the traps of the eastern hills, and between the two a totally different set of shaly rocks occurs, the general dip of which is also to the west.

Among the eastern hills again, and always extending along their length, varieties of trappean rocks appear, and here again smaller bands of shale recur, while the most easterly variety of rock is different from all the rest, and may be traced at intervals, for miles, parallel to the general strike of the strata, from an islet in the harbour called Cross Island* by Seoree Fort, and Antop hill to the eastward base of Pulshachee (Doongree) Hill.

The dip to the west is not always equally marked or equally high, nor is a dip always evident, particularly among the traps, while the fresh-water beds, or shale series, are in some places horizontal, or bent into open curves; but the facts with regard to the inclination of the beds are so frequently observable that, taken together with the form of the ground and arrangement of the rocks, quite sufficient evidence is seen to lead to the conclusion that Bombay Island like any other part of the neighbouring country is formed of a series of regularly stratified trap rocks; its greatest local peculiarity being, that interstratified with the traps various bands and layers of shaly rocks which have been deposited in water occur here.

General section.

Taking this view of the structure of the Island, and bearing in mind the main fact that all the inclinations of the trappean strata, together with most of those in the associated shales, have a common westerly dip,† it

* Communicated by Dr. Leith, who also informs me that this rock may be found in Salsette, continuing in the same line somewhere near the Vehar Lake. It is also referred to by Dr. Carter in notes "on the geology of the Islands around Bombay," (Journal, Bombay Branch Royal Asiatic Society, Vol. VI, page 178).

† A similar westerly inclination of the beds may be traced in the neighbouring trappean island of Elephanta, more prominently still in Trombay, and is also found in Salsette.

follows that the whole island presents an ascending series of stratified deposits commencing with the black basaltic rock of Seoree on the east, succeeded by the traps and shales of the eastern hills, which are overlaid again by the shaly beds seen at both sides of the flats, and terminated by the basaltic beds of Malabar ridge and Wurlee; as shown in the Sections, Plate II. It will be seen from these Sections that the natural arrangement of the rocks closely coincides with that given by Mr. G Clark (ante. p. 2). Other representations of the facts might possibly be given, but, as it appears, not consistently with the interpretation of the case suggested by even slight acquaintance with the ground; and this interpretation is not the less likely to be correct on account of its simplicity.

The key to the arrangement of the rocks is their stratification, and any difficulty which may have prevented the adoption of Mr. Clark's opinion probably arose from overlooking the fact that the stratification is found to prevail in both the aqueous and igneous rocks. It is well known that trappean rocks are frequently stratified or interstratified with chemically or simple mechanically formed aqueous rocks; but then the former are generally, more or less, easily discoverable to be finely granular or flaky, or else are found to have some of the internal or external characteristics of deposited or precipitated rocks, the particles of which have been arranged either by gravitation or the action of currents, or both. Otherwise they may resemble tabular basalt horizontally, but irregularly, spread out in sheets, or they may occur closely associated with other igneous rocks, the volcanic origin of which is more

Rocks stratified.

Mr. G. Clark states that it is general along the adjacent portion of the western coast of India, while it has been observed by ourselves to continue for 50 miles to the northward, and also to extend for several miles inland.

evident; or there may be circumstances connected with their position and ingredients from which their subaërial origin may be inferred.

The trappean rocks on Bombay Island form the mass; the occurrence of interstratified, decidedly aqueous, beds being exceptional in the larger trappean area of which these form only a small detached part. In their very regular and continuously parallel stratification they, like the rest of the great trappean formation of Western India, bear a striking resemblance to chemically formed aqueous rocks, while they all have an igneous composition, admitting of numerous mineralogical variations, as well as those of structure, texture, and color. Although they might all be termed at a first wide view basaltic, most of them would be called by English observers greenstone, but many of them seem to have a complex internal structure, some resembling varieties of felstone, or an intermediate combination of the minerals which go to form each of these rocks, while many of the more earthy amygdaloidal kinds might be called compact volcanic ash. Although some of the beds change in appearance along their extension, there is much more variety observed in passing across the strike from one bed to another, and yet this variation is not sufficiently limited to any horizon to deprive the whole series of its unity of character.

General aspect of Traps.

Taken together the rocks of the island present a great number of varieties, among which may be found the common gray and bluish sub-granular, sub-crystalline, and semi-compact intermediate trap which has been called trappite by Dr. Carter; the siliceous looking basaltic trap of Malabar Hill range, hard enough to mark glass; the black basaltic trap of Seoree which does the same; vesicular amygdaloidal trap containing geodes filled with quartz and zeolites; the soft soapy variegated ash of the eastern side of the Island; the red volcanic breccia of Sion; the

Varieties.

white trap of Dharavee; various kinds of ferruginous and flaky ash, and the intertrappean shales, sandstones, and flags, derived apparently from mechanical disintegration of the trappean rocks.*

* Whether the Bombay trap rocks were subaërial or deposited in water is an interesting question, which we are not quite able to decide from mere inspection of the ground.

The regularity and widely extended parallelism of their stratification and the flaky character of some of the ashy beds, together with the prevalence of amygdaloids and a certain internal lenticular structure frequently found in aqueous rocks, might be taken as affording some evidence that they were deposited beneath the sea. In several of them hand specimens could be found very nearly resembling the subaqueous trap rocks of Limerick in Ireland, and bands of ferruginous ash occur in places with as well defined a demarcation from the adjacent beds as could be found in many aqueous rocks. There is, on the whole, but little evidence of the alteration of one bed by the heat of another, not more perhaps than might have occurred under water, while the presence of what we are led to believe are conformable aqueous shales, occurring in the same manner as some of the more ashy beds, might be supposed to favor this view. On the other hand, most of the internal evidences which aqueous rocks afford concerning their origin are wanting, lamination is very rare, current marking, so far as we know, has never been observed, and the slight evidence which the shales might be supposed to afford is questionable, for it would not follow that because they are subaqueous the traps should be so also. The fossils which they contain are fresh-water forms, and if these are supposed to have been washed down into an estuary, the absence of marine forms remains to be accounted for before we can suppose the shales to have had other than a fresh-water origin. Arguing from analogy, any lake sufficiently extensive to have received the whole of the traps of Western India would require a peculiar geographical disposition of the land, with large river systems, in order to keep its water fresh, but of this no geological record is known to exist, nor can we venture to speculate upon the distribution of land and water during the period at which the traps were deposited.

Both subaqueous and subaërial varieties might exist together if the traps had been ejected in shallow water, above which they might in time be raised or raise themselves, when one variety of possibly subaqueous bedded trap might have been overflowed by a more basaltic kind, as would seem to have occurred in Bombay Island. The breccia of Sion points to the existence of a volcanic vent at no very great distance from where it is found, but we have not as yet any evidence regarding its precise locality, or as to its original condition whether subaërial, subaqueous only, or submarine.

Foci of eruption.

The *foci* of eruption of the traps of Western India and their precise method of deposition in such wide spread sheets, flows, or beds are as yet unknown, (unless the slender possibility of their having come up through the comparatively few dyke-fissures which they contain may be supposed to do away with the necessity for larger volcanic vents,) but these are questions which, although connected with the geological structure of Bombay Island, belong in a greater degree to other districts, where the rocks are much more largely developed and exposed.

3.—Rocks of the Island.

Tertiary, probably Eocene

7. Alluvium; sand, and recent conglomerate.
6. Basaltic trap dykes.
5. Fossiliferous fresh-water beds, or shale series.
4. Amygdaloidal trap passing into solid gray trap and containing a band of breccia, and perhaps also the white trap of Dharavee.
3. Gray trap associated with fresh-water beds, shales, and flags.
2. Trappean breccia of Sion Hill, &c.
1. Black basaltic rock of Seoree, &c.

1.—*Black basaltic rock of Seoree, &c.*—This black rock is very peculiar; it has been described as "a Lydian stone, a black jasper or "chert, the result most probably of the action of the volcanic rocks "around on a stratified clay bed, the strata being still traceable, with "the same specific gravity as jasper, striking fire with steel, and being "luminous when rubbed in the dark, scratching glass and giving out "a strong sulphurous smell;" it is stated to dip at an angle of about 25°, and to split into semi-prismatical masses.—*(Dr. Buist).*

It is also said to "assume the appearance and structure of a coarse "black homogeneous jasper, and to contain fragments of trappite and "amygdaloidal rock."—*(Dr. Carter).*

We should feel inclined, from its aspect merely, to call this rock black compact (contemporaneous) melaphyre. It has a hardness slightly below 7·, and is very splintery, with much the character described by

Dr. Buist. The atmosphere does not affect it deeply; it is highly compact, has a semi-lustrous glistening conchoidal fracture, contains a few nodules of coarser trap rock, and here and there a scattered glassy-felspar crystal may be detected in its fracture. It is traversed by lines resembling lamination, in some places breaks into slab-like pieces, and in others has much the appearance of pitchstone. Before the blow pipe it fuses with but little greater difficulty, if any, than either the gray or basaltic trap of the island, and its analysis gives the following results:—*

Silica	61·60
Alumina	27·12
Sesquioxide of Iron...	2·12
Protoxide of Iron	4·60
Oxide of Manganese ...	trace.
Lime	2·10
Alkali	trace.
Loss—Water and organic matter ...	2·46
	100·00

* In composition it does not seem to resemble closely either felstone, greenstone, or basalt, the quantity of alumina it contains being much in excess of the proportions usually found in felstones, according to the analyses quoted by Jukes, (Manual of Geology, 1862, Chap. IV, p. 61, &c.,) while its silica is below the average amount.

Compared with analyses of greenstones given by the same authority, the quantities of these two largest constituents of the Seoree rock are both in excess, the closest resemblances, excluding fractional quantities, being to melaphyre, (above the mean of which its excess of silica is 9·, and that of alumina 6·;) or else to diorite, in which case these quantities are also larger, thus—

	Melaphyre. (Mean of Analyses by Durocher.)	Difference.	Seoree Rock. Analysis.	Diorite. (Mean of Analyses, Durocher.)	Difference.
Silica	52	+ 9	61	53	+ 8
Alumina	21	+ 6	27	16	+ 11
Potash	1		trace.	1	
Soda	4			2	
Lime	6	— 4	2	6	— 4
Magnesia	4			6	
Oxides of Iron and Manganese	9	— 3	6	14	— 8
Loss by ignition ..	1		2	1	

2. *Trappean breccia.*—This rock is met with in several places: its structure changes greatly, and it is often greatly decomposed; in some places it seems to pass into, or to be replaced by, a soft ashy

The mean analysis of basalt as quoted by Jukes, differs also from that of the Seoree rock, the same two chemical constituents being more abundant in the latter by 13 and 14 per cent. respectively.

Comparing it in the same way with dolerite, as tabulated in the same work, we have the following :—

	Basalt.	Difference.	Seoree Rock.	Dolerite.	Difference.
Silica	48	+ 13	61	51	+ 10
Alumina	13	+ 14	27	14	+ 13
Potash	1		trace.		
Soda	3			3	
Lime	10	— 8	2	10	— 8
Magnesia	6		0	5	
Oxides of Iron and Manganese ...	13	— 7	0	14	— 8
Loss by ignition	3	— 1	2	1	

Its analysis, exclusive of the alkalies the absence of which, however, is an important difference in all these cases, very nearly approaches the maximum one of those given by Jukes of the trachytic lava called clinkstone, which is subjoined for the sake of comparison :—

	Maximum.	Minimum.	Mean.	Difference from mean.	Seoree Rock.
Silica	62·	54·	57·7	+ 3·8	61·60
Alumina	24·	17·	20·6	+ 7·6	27·12
Potash	9·	3·	6·	— 6·	} trace.
Soda	14·	3·	7·	— 7·	
Lime	3·5	0·	1·5	+ 0·5	2·10
Magnesia	2·	0·	0·5	— 0·5	·0
Oxides of Iron and Manganese ...	4·5	1·5	3·5	+ 3·12	6·18
Loss by ignition ..	3·5	1·0	3·2	— ·73	2·46 and a trace of Oxide of Manganese.

But clinkstone is even more similar in composition to the basaltic trap of Malabar Hill as will be seen upon comparing its analysis with that of the latter rock, given further on,

decomposed looking rock, and owing to the circumstance that it thins and thickens rapidly, its position in the series (if it has only one) is very difficult to determine. Its colour changes from red to white, green, blue, or brown, but its mixed, mottled, and heterogeneous, appearance distinguishes it from other varieties of the traps with which it is closely associated. It is by far the most volcanic looking rock in the Island; we were unable to discover any clear evidence that it forms the upper surface of an intrusive mass occupying a huge fissure in the other rocks; planes of stratification in it are generally absent, but its longitudinal arrangement parallel to the strike of the other beds of the Island shows the probability of its occurring as a large lenticular and contemporaneous mass.*

* At page 200 of 'Papers on the Geology of Western India,' Dr. Buist says of the breccia near the Flagstaff Hill east of Parel Tank, that 'where it is uniform in texture, it is cut up for water-troughs and aqueducts, being soft when first exposed to the air, and harden ing afterwards without abrasion or decay, in this respect resembling laterite.' He calls it trap-tuff, and quotes from a paper by Dr. Carter, in which it is stated closely to resemble the *Rothliegendes* of the *new red sandstone* series called also Exeter conglomerate, while its argillaceous, mottled, and ferruginous character ally it to the laterite. It is unnecessary to say more than that these resemblances are not general, if they do exist; it is very different from any portion of the *new red sandstone* which we have seen, and it has a much less ferruginous aspect than any laterite which has come under our observation. Neither docs it afford any kind of proof that laterite is only a variety of intrusive igneous rock as Dr. Carter seems to have inferred.

The latter author mentions, at page 150 of the same volume, a granitic looking fragment of white diorite, which with fragments of coarse trap was found by Dr. Leith imbedded in black semi-jaspideous rock between Wadalla and Antop Hill. In another paper (Trans. Bombay Asiatic Society, No. XXI, Vol. VI, page 178), the author connects this circumstance with the occurrence of a piece of pegmatite in a basaltic dyke on the Island of Carinja, one of the Bombay group. Supposing the black semi-jaspideous rock to form *part of a dyke*, the occurrence may be explained on the hypothesis that the fragments were brought up with the intruding rock, but the evidence connected with the trappean breccia of this district was not found sufficient to enable us to say at what place it issued from greater depths on its way to the position which it now occupies.

3. *Gray trap associated with 'fresh-water beds,' shales, &c.*

4. *Amygdaloidal trap passing into solid gray trap, containing a band of breccia, and perhaps the white trap of Dharavee.*

As these two divisions of our list are closely connected and taken together form all the hills and rocks on the east side of the Island except those of Sion, Antop Hill, Seoree, and some places about Mazagaon, we include them for the sake of convenience in one description.*

The mass is principally gray or blue trap, with a composition and appearance resembling some greenstone, with the peculiarity, however, that it is stratified almost exactly like an aqueous rock. Such varieties of rock, if found in Great Britain *without* planes of stratification, would be called greenstone, and if they happened to be bedded, they would be called compact or amygdaloidal ash, as the case might be. The more compact varieties become in many places amygdaloid, and large tracts, particularly about Parel, are almost entirely occupied by the latter rock.

Upon the high ground of Race Hill is a lenticular trappean band of a peculiarly brecciated and vesicular character, dying out both to the north and south, and evidently interposed between the strata of the

* The gray trap of the eastern hills, part of that called by Dr. Carter trappite, is said by him to be chiefly composed of crystalline felspar and hornblende, together with a little argillaceous earth. In the larger-grained specimens he says "we shall find tabular crystals of white felspar, *amorphous crystals*† of green hornblende, a small quantity of greenish or bluish argillaceous earth, and more or less green earth, olivine, and small particles of *peroxide of iron*, probably titaniferous iron or *rutile*, from its rich brown red colour in some parts, *most of which are caught up by the magnetized needle*† in their natural state when the rock is pulverised; cavities are sparsely scattered in it, which contain varieties of scolezite or needle stone." The rock seems to fall within the class called intermediate traps by Professor Jukes, its principal ingredients being felspar and hornblende or augite, but possessing many complex varieties in its composition, some of the beds being more siliceous than others, and yet seldom or never taking the ordinary appearance of felstones, or being acted upon to the same extent by the atmosphere as they are.

(† These italics are our own. Particles caught up by the magnet are more probably magnetite, (magnetic iron,) the other minerals mentioned being very faintly, if at all, attracted by the magnet.)

gray trap; it is included in the volcanic breccia by Drs. Carter aud Buist, but seems to be a separate band of very similar rock.*

Other brecciated trappean rocks occur along the shore near Mazagaon. In one of these Dr. Leith informs me he found what appeared doubtfully to be fossil bones, but was unable to make out any traces of bony structure.

A coarse white variety of trap, in appearance much resembling a sandstone, occurs at the northern end of the Island about the village of Dharavee.

Associated with these gray trap rocks, and affording good evidence of their being stratified, are several narrow bands of 'sedimentary' shaly rock; they contain some fossils (obscure plants and Cyprides), and consist of brownish or gray shales, always having a dip to the west, though some times at a very small angle. They seem to occur irregularly on different horizons, and Dr. Buist mentions that in one place they have been cut up by the intrusion of a trap dyke.

5. *Fossiliferous 'fresh-water beds,' shales, and flags.*—The rocks last mentioned as associated with the gray traps are among the lowest of this series, though the general description of them has been reserved for the largest group. This seems to occupy much of the ground below the surface of the flats, where trappean rocks are doubtless interstratified with these sedimentary beds. They run all along the eastern base of Malabar ridge, and are well exposed there in several places, to be hereafter pointed out. In the flats again and at their eastern side they also appear, having generally a light brown colour and fine texture, altogether very similar to those lower bands which occur among the traps of the east of the island, but at the sluices their colour was observed to be a dark-green passing into black. Bands of a white colour and siliceous are associated with them,† and they all

* This is the rock alluded to by Dr. Buist, as becoming hard under exposure to the weather.

† Dr. Carter.

seem to have been formed from the fine detritus of volcanic matter. Flaggy beds occur among these shales; thin slabs of considerable size, and bearing the impressions of large vegetable stems, having been recently raised during the operations connected with building the gas works on the Parel Road at the eastern side of the flats (1863).

This shale series has been proved almost everywhere to be highly fossiliferous, but we had neither the good fortune nor the opportunity to discover more than a few specimens of *Rana pusilla* at the sluices, and to observe that the shales there, as well as in nearly every place where we saw them, contained quantities of vegetable impressions and numbers of little *Cyprides.**

* An extended notice (with illustrations of fossils in the Volume of Plates) concerning the organic remains found in these rocks by Dr. Leith, their first discoverer, and by Dr. Carter is given by the latter in his paper already quoted; (Journal Bombay Branch Royal Asiatic Society, Vol. V, page 161,) and see Geological Papers on Western India, pp. 131, &c.

The following is a list of the fossils found:—

ANIMALS.

VERTEBRATA. Reptilia.

Testudo Leithii. Carter.

Amphibia.

Rana pusilla. Owen.

Rana sp. larger than *R. pusilla* (only footprints found).

ARTICULATA. Insecta.

Elytra of beetles.

Crustacea (Entomostraca).

Cypris cylindrica.—Sow.

C, semi-marginata.—Carter.

C. sp.

MOLLUSCA.

Gasteropoda.

Melania?

Pupa??

6. *Dykes.*—These will be mentioned amongst the details given below; they are not greatly different from the ordinary trap, but somewhat more compact or concretionary, or of slightly different texture from that of the bedded rocks; they penetrate, and they sometimes yield more rapidly to the action of the atmosphere than, the traps in their vicinity.

Dyke-like masses occur in the volcanic breccia of Sion, but from their similarity to the neighbouring rock, it is all but impossible to say that they do not owe this appearance to the occurrence of parallel master-joints.

Basaltic trap of Malabar Hill.—This is an extremely hard dark variety of bedded trap; it marks glass, yields but little, and in a peculiar manner, to the atmospheric action; in some places the only effect produced being a slight superficial oxidation of its combined iron, in others it is traversed by strong joints, between which large spaces have been formed, and most of the remaining angles, owing to a rudely developed concretionary structure, have been partially rounded off.

Although many of its surfaces, both horizontal and vertical, exhibit a more or less hexagonal network of divisions, filled with either white quartz or zeolite veins, thus indicating a concealed prismatic structure, it is rarely, and then but rudely, columnar. The thickness of the mass is uncertain, as it may have extended further in a vertical direction; in places, however, it exceeds 80 feet.* The composition of an average

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PLANTS.

Leaves, stems, and seeds, all more or less indistinct, and wood, chiefly dicotyledonous. The "cormiform" and "globose" roots described and figured by Dr. Carter, and of which the original specimens are preserved in the Museum of the Bombay Branch Royal Asiatic Society, have very much the appearance of concretions, and their organic origin must be considered extremely doubtful.

* This rock is very finely columnar in its extension to the north beyond Bombay Island. See Dr. Carter's Contributions to the Geology of Western India, (Journal, Bombay Branch Royal Asiatic Society, Vol. VI. pp. 174-6.

specimen is subjoined, from analysis made at the Geological Survey Office, Calcutta, by Mr. A. Tween :—

Malabar Hill basaltic trap.

Silica	59·80
Alumina	22·75
Sesquioxide of iron	4·92
Protoxide of iron	5·88
Lime	1·80
Alkali	2·50
Water and organic matter ...	2·36
	100·00

7. *Alluvium; sand, clay, recent conglomerate, &c.*—As the names of these almost include their description, they do not require further notice in this place.

4. Relations between the Form of the Ground and its Geological Structure.

A palpable connexion exists here between the form of the ground and its structure. The elongated shape of the island is plainly due to the direction of the beds or flows of trap rock of which it is chiefly formed, and the reason that these have assumed in most instances a ridge-like appearance is because they have been tilted so as to make (somewhat of) an angle with the horizon, thus exposing beds of different texture and capable of different resistance to the powerful action of erosion under which they received their present forms, the result being that certain harder bands withstood this action more than others, and thus determined the direction of the lines of more lofty ground.

Rocks tilted.

Another circumstance to which the varieties in the form of the ground may no doubt be largely attributed is the occurrence of the fresh-water beds among the harder trap rocks, presenting an even greater difference of texture as regards the whole group than exists among the trap rocks themselves. Upon these soft fresh-water beds denudation would produce the greatest results, and probably where they lie most nearly horizontal the widest flats, terminating at the steepest features, might be found; thus we see that where openings have been made in the flats sufficiently large to expose the stratification of the rocks beneath, they are found to dip, but slightly, to the west, or undulate about a nearly horizontal plane, and where the flats are bounded by the Malabar Hill range—its massive flows of hard basalt overlying the softer shales with a well defined dip to the west—there the characteristic form of ridge with its short steep eastern face and longer slope to the west is most clearly developed.

Beds of unequal hardness.

Beyond the limits of Bombay Island other facts exist tending to show that denudation, together with the stratification of the traps, is the principal cause to which the features of the ground in the vicinity may be attributed.

The flat plain of the Deccan to the east coinciding with the horizontal stratification of its rocks, and the steep vertical cliffs of the Ghâts or Syhadree mountains along its western edge, are illustrations upon a grand scale of the features usual under such stratigraphical conditions as obviously resulted in their production. Westwards, however, in the neighbourhood of Bombay, the strata are found to incline seawards, and the erosion acting along their strike has in most instances given rise to features coinciding therewith. The coincidence of much of the coast line itself with the general strike, and the absence of long head-lands projecting to the west, may be adduced as large examples of the relation between geological structure and physical form, while the prolongation of the Malabar Hill range to the northwards* and into promontories at Wurlee and Malabar Points in the Island of Bombay may be taken as smaller features due to the same cause.

Denudation.

As has been already mentioned, the occurrence of these fresh-water beds has probably caused much of the diversity of form which the Island presents, and although the geology of the Deccan and of Western India is hardly well enough known to enable us to speak with certainty of the smaller details, it may be said that these fresh-water beds are an exceptional feature in the trappean districts of Western India. Analogues probably exist, such as the fresh-water limestones, which are in some distant localities interposed between the traps, but over many large trappean areas, which have been traversed by us, all these fresh-water deposits seem to be entirely absent. No good grounds have been assigned for a supposition which has been advanced† that the strongly marked

Fresh-water beds exceptional:

* Dr. Buist states that the basaltic ridge 'stretches to Bassein' about 27 miles to the northwards, where fine basaltic columns may be seen.

† Geological Papers on Western India, page 189.

flows or beds so well exposed in the steep precipices of the Ghâts are each separated by some of these softer beds, and their absence being the rule, it is somewhat singular to find them alternate so frequently with the traps within the Island of Bombay, for, although they may be merely local, their accumulation at different positions in the section marks the occurrence of intervals of rest during which the direct accumulation of igneous or trappean materials ceased, in their vicinity at all events, and if such breaks took place there they probably occurred from time to time elsewhere as well. The irruption of trappean materials having been discontinued sufficiently long for vegetation to cover the ground, tropical rains would perhaps fully account for most of the results immediately following, and indeed the existence of floods is suggested by the pieces of drift wood mentioned by Dr. Carter in the papers quoted (page 133). Whilst we compare the general absence of these fresh-water beds in the trap rocks with their local abundance at Bombay, it must be recollected that, although the Island presents a section the depth of which is estimated at 1,200 or 1,500 feet, there is a possibility that its rocks belong to a higher place in the series than those of the main-land, and may therefore be quite unrepresented along the Ghâts, where lower beds would consequently occur. As indications of this possibility may be mentioned the slight but general dip to the west which has been observed for very considerable distances to the north and south of Bombay, leading to the inference that an axis of curvature runs along parallel to the north and south range of the Ghâts, and between them and the sea: Some of the furthest beds visible on the west of this axis would be those of Bombay Island, and even if the low dip of 10° to the west be assigned to them and a large allowance made for curvature as well, it will be seen that, if their present outcrops were produced over the intervening country to the

abundant in Bombay.

Rocks of Bombay high in series.

east, they would pass far above the highest pinnacles of the Ghâts, which are situated from 30 to 50 miles inland.*

It should also be remembered that these fresh-water beds have been traced but a short way, comparatively speaking, beyond Bombay Island, while many of them appear to thin out both to the north and south within its limits, and if their occurrence, or the cause which produced them, was merely local, we have no warrant for supposing that they extended further in one direction than another. The most natural supposition regarding their occurrence seems to be this, that the trappean flows (considering these to be subaërial) assumed here a more lenticular form than is elsewhere apparent, and that flows approaching from opposite sides left shallow basins, which became the repositories of mud and sand, the results of disintegration of the trap washed down by rain during long intervals of cessation between the eruptions of the trappean materials; intervals in which the muddy basins became the receptacles of many forms of organic existence: and then subsequent trappean flows overran and covered up these lacustrine deposits, long afterwards to be exposed again by denudation, nearly as we see them now.

Possible cause of appearances.

* The westerly dip of the traps may be traced for several miles to the east of Bombay, and is particularly conspicuous in the harbour upon the Islands of Trombay, Elephanta, and Carinja. At Matheran, however, and in its neighbourhood, the beds of trap are as horizontal as at the Ghâts.

5. Denudation.

The denudation, or wearing away, of the rocks has had so much to do with the form of the ground that it deserves some notice.

All recent geological inquiries in this direction tend to show that large as were the results previously attributed to this action, this estimate fell far short of the reality; that to its powerful agency, more particularly the portion of it due to atmospheric causes, are to be ascribed almost all the grand and varied features of the ground in those countries where volcanoes do not exist, or have not recently been active. Bombay Island presents no exception to this observation, for although here and on the neighbouring main-land the rocks are almost entirely igneous, it is chiefly from general elevation, during the process of denudation or the combinations resulting from the disintegration of the land either when moving or in a state of rest, and not from any direct local exertion of volcanic agency, that the ground has received its present features.

Cliffs of the Ghâts.

The grand precipices of the Ghâts, which give such interest to the distant portions of the landscapes about Bombay, present the finest examples of seaworn cliffs formed probably during a long period of gradual elevation; while in the extremes of tropical heat and wet, powerful sun and swollen torrents, each acting for months together on the easily abraded trappean rocks, we have instances of atmospheric action likely to produce enormous effects. When it is considered, too, that an unknown thickness of rock has been worn away from above the very highest of the Ghâts' mountains, themselves more than 4,000 feet above the sea, and that their steep western precipices, with heights of 2,000 feet, are situated so many miles inland; while portions of the same group of rocks in their extension now form the coast line, and further, that nearly this thickness of 2,000 feet of solid rock has been, in all probability, excavated and removed from off the intervening country, some idea may be gained of the vast extent of this action of denudation.

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To this cause the occurrence of all the islands along the coast is due. Its effects upon Bombay Island itself are evident, in the fine crags overlooking the western side of Back bay,* the breach in Malabar ridge at the Vallade, the irregular outline of the Island, the wide space occupied by the flats, and the picturesque forms of the hills on its eastern side, with deep inlets and shallow bays, now almost filled with detritus, washed down by the rivers of the main land. The peaked outlines of the hills at the north of the Island are derived from the gradual degradation of the tough breccia of which they are composed, and not from any force of protrusion of their material, and their similarity to each other and their conical shape are due to the almost total absence of clearly defined stratification and to the general sameness in the structure of their rocks, while stratification alone has influenced the form assumed under denudation by the rest of the hills within the Island. The texture of the trap rocks presents so little difference in places that the denudation has not very variously affected them, but the solid ridge of Malabar Hill on one hand shows how it has been resisted, while the inlets on the east and the abrupt slopes overlooking the harbour exhibit its results upon much softer beds. The flats, again, present an example of this action upon soft beds: the low ground about the Fort and Colaba are places where its effects have been unusually great, but here the angles of dip are extremely low, and one of the hardest but most splintery rocks in the Island, that of Antop Hill, appearing at intervals with wide gaps between, is an instance of the way in which such rocks yield to this force.

Vast extent of denudation.

* These cliffs, owing to the rapid rate at which building has lately proceeded in Bombay, have been so extensively quarried that they now present an artificial appearance, which, however, cannot conceal many of the prominent features, such as the great natural clefts or vertical separations of the rock. The lines of flow or stratification are also visible in many places, although the general tendency of fresh fractures on a large scale is to conceal such lines in these hard rocks.

The gap in Malabar ridge at the Vallade was probably produced by some such circumstance as undulation or approach to horizontality connected with the soft fresh-water beds which underlie the basalt; and nearly every point in the Island presents some instance of the effect of denudation modified by local circumstances.

It is difficult to distinguish those features in the Island, which may be due to marine or to subaërial denudation; probably all have been originally caused by the former, but subsequently reduced by the wasting agency of the latter. Both varieties of the action are in operation still and the latter at least is proved to have been in existence at a very remote period by the occurrence of the fresh-water beds, which were doubtless produced by natural causes operating very much as they do at the present time.

Both marine and subaërial.

6. Elevation and depression.

Closely connected with the denudation are the actions of elevation and depression, which have exposed different portions of the ground to its influence.

It is at least possible, if not most likely, that such cliffs as the Ghâts present were formed either while the ground gradually emerged from the sea or sank beneath it. In either case an immense period of time must have elapsed during the operation of cutting these cliffs, and supposing neither great elevation nor depression to have taken place, a period as indefinitely long perhaps would be required to eat back from the present coast line to 40 miles inland through a height of some 2,000 feet of rocks to reach the place where the Ghâts' mountains now rise from the low Konkan. But assuming that the land was worn away during its elevation, then, even before the Ghâts' cliffs themselves were formed, denudation had been going on, reducing the once higher country to a lower level; as is marked by the many flat topped mountains rising above the

Long continued.

general height of the range, and as the summits of these hills suffered erosion also, there is nothing to show how much higher they may have reached, or when an action, already proved to have been so extensive, may have begun to operate.

The very magnitude of this vast action of denudation which has left mountains two and three thousand feet higher than the plateau of the Deccan,—itself two thousand feet above the sea,—inclines us to attribute it to the strong agency of marine erosion rather than to that of atmospheric origin. Cliffs are to be found on the sides of these lofty mountains quite of the same character as those of the Ghâts below, and if these were formed by the sea, as is almost beyond a doubt, then this portion of the Deccan must have experienced an elevation of many hundred feet above sea-level.

As the excavation of the cliffs and glens could only have proceeded at a slow rate, the time occupied by the elevation* so as to bring all parts of the country within reach of the sea's surface, at which alone such active destruction of the rocks goes on, must have been a period of great length; but it is perhaps as impossible to say when it ended as when it commenced, and, if the elevation were so slow as to be almost imperceptible, it might even continue at the present time.

Recent.

Whatever movements of the ground affected the country to which we have just alluded no doubt extended also to Bombay Island, but here we have further evidence of very recent actions both of upheaval and depression. The blue clay of the flats containing Mangrove roots is said† to have been found near Sion, and in other parts of the Island, undisturbed at places now beyond the reach of the sea. Above this, and at an elevation of 10 feet higher than sea-level, are sea-shells, gravel, and sand, loose or cemented

* Assuming that it was during a time when the land was being raised that the cliffs were formed.

† Dr. Buist, 'Papers on the Geology of Western India', pp. 181-4.

into a variety of open shell-limestone 3 to 10 feet thick. From this it follows that the clay containing the roots of Mangroves, which only grow within the tide marks, must have been depressed in order to allow the stratified deposit of sea shells and gravel to have accumulated, and afterwards both must have been elevated as high at least as the position in which they are now found.*

When the shell-concrete or recent conglomerate was deposited so widely as it is found to have been all over the flats this Bombay district must have consisted of a group of several Islands, a fact which has not been overlooked by previous observers. Mahim at its northern end is mentioned in an old manuscript as forming a distinct Island,† and Dr. Fryer, who visited Bombay in 1674-75, alludes to the same fact.‡

That much of the low ground in the Island is not now submerged during the prevalence of westerly gales in the monsoon, while partly due to elevation of the land, is also largely the result of artificial embankments and floodgates at the Vallade, at the sluices near Wurlee Hill, and on the road from thence to Mahim wood, as well perhaps as to the natural barriers in the form of beaches, which the sea has thrown up at both the north and south ends of the Island.

* The places where these deposits occur are not particularly pointed out; they are said to be visible all round the Island, and are treated of at considerable length by the above author. Where we have seen them their position is that which is described, and the fact of an elevation seems to be established; but knowing that portions of the Island are at a lower level than high water mark, some uncertainty as to the amount of these changes of level has been felt. This, if it existed, was doubtless removed by the extensive opportunities which Dr. Buist had of observing these deposits. At somewhat distant places, however, along the coast of the North Konkan, clear evidence of an elevation of the land was seen in the existence of similar littoral deposits considerably above high water mark, and this is strongly corroborative of the facts observed in Bombay Island.

† Dr. Buist, Geölogical Papers on Western India, 175.

‡ New account of East India and Persia, in eight letters, being nine years' travels, begun 1672 and finished 1681, by J. Fryer, M. D., *London*, 1698, fol. p. 47.

A considerable quantity of blown sand occurs near Mahim, where the low scarp which the sand presents to the west exposes a section through an old graveyard now completely buried beneath the sand.

7. Water.

Although the Island does not contain any thing more like a river than a few sluggish creeks and drains, or intermittent streamlets, which flow only during the monsoon, still a plentiful supply of fresh-water is to be obtained from among the various strata of which it is composed.

As might be expected the greatest quantity is found in low situations. Where wells are sunk in the saline blue clay the water is brackish; in other situations it is more or less pure.

The basalt of Malabar Hill is said to afford but little water, more being found in the traps to the east; any of the traps, and particularly those containing many fissures or other lines of separation, will afford water just as it is obtained all over the Deccan or other trappean countries by sinking wells, which are filled by infiltration; the supply depending upon the quantity of fissures and the extent of surface upon which the water falls and from which the supply is derived.

None of the recent strata of the Island seem to be particularly porous, as they have the power of separating salt water from fresh, where wells are sunk through them along the coast to below the sea level, and to this source of supply is perhaps due the rising and falling of the water in certain wells depending upon and corresponding with the state of the tide,* but this is a question beyond our reach to consider further for want of more ample data.

* An interesting section upon this subject will be found in the paper by Dr. Buist before alluded to; he says the supply of water is sufficient for nearly half a million of people, although the annual evaporation equals the annual rain fall (on an average 70 inches); that wells sunk in the shell-concrete or recent conglomerate furnish good water, but when they reach the saline clays beneath it becomes brackish; that the (fresh-water beds) shale series

8. Faults.

The only well marked fault which has been observed is that at the north end of Antop Hill and between it and Muddly-Antop.

The difference of the rocks on each side is very great, and the change from one to the other sudden, but neither of these are sufficient reasons for supposing a fault to exist. This is one of those cases in which, although not perfectly clear, the existence of a fault is so strongly indicated by local circumstances that we feel warranted in accepting it as an explanation of the facts before us. As these circumstances will be mentioned in the details further on, reference to this subject will be found at that place.

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supply abundance of fresh-water, and that tidal fluctuations in the level of the water in those wells sunk in littoral concrete near the shore can be observed daily, but at the distance of a mile from the sea they are easily discernible at spring tides; that the quality of the water is not sensibly affected by any connection with the sea which may exist, and it is suggested that the change of level is caused by the ponding back of the usual discharge (? filtration) from the shore to the sea. Springs are mentioned further on, and in one case during the excavation of a tank in trap rock, half a mile from the sea and near the Baboola Tank, a great rush of water containing half as much salt as sea water is stated to have entered this near the bottom. From the heights given upon the large Map of Bombay Island published by Government this tank would seem to have been sunk considerably below sea level.

9. Details.

It being possible to follow more or less perfectly the natural order of the rocks, by commencing at the north-east corner of the Island, we shall take it first, proceeding with the description from thence southwards, and afterwards towards the west.

About Sion the ground is steep and hilly, the eminences more or less conical, rising somewhat abruptly from the muddy flats, salt pans, and shallow bays, which are left dry in that neighbourhood by every tide. These hills, although not high, are all picturesque, perhaps more so than any other parts of the Island; the principal ones are

Sion Hill, and vicinity.

Sion Hill upon which Sion Fort is situated; another between the village of Sion and the Railway (in course of removal for purposes of reclamation near Bombay City); Pulshachee (Doongree) Hill south of Sion Fort, and still further southward Antop Hill. The heights of the latter are from 85 to 127 feet, but the remainder of the ground near this is low, flat, or undulating. These hills present an exception to all others in Bombay Island, for while the rest have more or less the character of ridges this character is not here prominent, and can only be traced obscurely in the *alignement* of Antop and Pulshachee Hills; in a low elevation which connects ground near the latter with Sion Hill; and in a persistent band of gray-trap, forming somewhat higher ground than occurs in its vicinity, which reaches (with regard to this locality) from the village of Wadalla to Riva Fort, broken through, however, and crossed by a portion of the flats south of the latter place.

The conical and highest hills are all formed of the red breccia, sometimes very lateritic in appearance, which has been called Tufa by Dr. Buist and forms part of Dr. Carter's "third effusion." We have Dr. Buist's and Dr. Carter's authority for its extending to, and occurring in great force on, the Island of Salsette to the northward, but southwards,

it would seem to die out as it is not seen, at least not with the same appearance, southward of Wadalla village. A somewhat close inspection of the ground leads to the discovery of obscure dips towards the westward in the breccia, and this is found to correspond with the inclination to the west observed in the gray trap and Dharavee beds. The extension of the breccia from north to south also corresponds with the run of the gray trap; and further, upon examining such situations as underlying rocks (if also corresponding to the obscure dip of the breccia) would be likely to appear in—namely, the eastern side of the exposure of the latter, and the deep hollows where the sea has cut across its strike—in these places a very different variety of rock is found, which, although locally varying, still so closely resembles the black-trap of Antop Hill that there is no reason to doubt its belonging to the same group. This black basaltic rock may

Antop Hill.

be all but traced from near Antop Hill itself northwards along the shore of Muddly-Antop just skirting that mass of breccia on the east; and a shingly bank or bar which almost connects Muddly-Antop Hill with Pulshachee Hill is evidently formed from the breaking up of this black rock. Still further in this direction, just below the magazine on the south point of Pulshachee Hill, the black-trap itself is seen cropping to the surface on the shore, as if coming out from beneath the breccia. It could not be traced onwards in this direction possibly because its surface may have been uneven before it was overlaid by the red breccia, but it re-appears again with somewhat of the appearance of horizontal bedding on the road from Sion to Matoonga close to the village of Agurwara. Here it seems to have been exposed by denudation at a place where the surface formed of it was slightly higher perhaps than elsewhere in the neighbourhood. The quantity exposed is small, and it is only visible in one or two localities close to each other.

Not far from the patch just mentioned the Sion Road passes by a causeway or embankment over a portion of the salt marsh or bay

between Matoonga, Muddly-Antop, and the neighbourhood of Pulshachee Hill. Close to this road and embankment there are pieces of rock strangely twisted and apparently much altered, projecting from the mud of the flats and skirting the edges of the bay; these are, although somewhat different, so like the rest of the black 'basaltic' material of Antop Hill that we cannot help thinking them the same. Although these rocks have a somewhat flinty appearance they are in places brecciated, and as it were present a rough passage from the black-trap into the red breccia, such as might occur from alteration produced by the breccia having overflowed the black rock in a melted state; and this fact,—taken in connection with the circumstance that portions of the breccia left by erosion project from the mass while the black rock appears close by all round them, re-appears as an inlying exposure, and occupies a lower position,—seems to warrant the conclusion that the whole of the Sion breccia is an intercalated mass of more or less lenticular shape interposed between the black rock and the gray-trap of Matoonga and Riva Fort which we have placed next above it in our classification of the rocks.

Taking this view of the position of the black rock below the breccia it seems to occupy a very natural position,* until we find it rising

* Either as a contemporaneously deposited or horizontally injected sheet of igneous rock. It has been thought by some observers to resemble an altered argillaceous deposit; if this were so, the depth to which the alteration had affected it would be very great indeed. Lines as much resembling lamination as those which it contains may be frequently observed in compact felstone and basaltic traps. And although its composition may resemble that of an altered shale, its structure does not bear out this supposition. Among the numerous intertrappean sedimentary deposits nothing has been noticed at all resembling it, nor does the effect of the overlying trap in altering the texture of these deposits ever (so far as our observations go) extend more than a few inches, or, at the most, a foot or two. The Basalt of Malabar Hill, although admitted by all to have been once fluid, has produced scarcely any perceptible alteration in the frog-beds at the sluices. Lastly, this very basalt of Malabar Hill, as typical an igneous rock as it is possible to conceive, has a composition just as much resembling that of an altered shale, as the flinty jaspideous rock of Seoree.

into a bulky elevation of 85 feet at Antop Hill. The ridge here formed by Antop and Muddly-Antop Hills (upon the western slope of which the English burial ground is situated) appears to be crossed by a fault which has changed the level of the lower black trappean rock, allowing it to abut against the breccia of the northern and last named half of the ridge. There are other suppositions, such as previous erosion of the lower rock and much inequality in its surface, which might account for the appearances here, but the difference in level is so much greater than occurs elsewhere, and the line of junction seems to be so straight and clearly defined (bearing about east 15° north), that a fault appears the most probable supposition to explain the positions of these rocks. The detritus from the hill lies so thickly upon its western flank that the junction of the breccia (which appears to occupy the hollow near the village of Gowaree) with the rock of Antop Hill could not be seen, but upon the supposition of the fault the breccia here may very possibly resemble that on the east side of Pulshachee Hill below the magazine.

From the nature of the ground on the west slopes of Antop Hill the black splintery rock, although close to the surface, is not well exposed, but on the east it forms naked cliffs; upon closely inspecting these, lines like those of lamination or fine stratification may be observed extending as if horizontally; some little cavities in the rock, too, are elongated in this direction, and numerous slabs detached from the cliff by the weather and lying at its foot are of a tabular character such as might be assumed by a flaggy rock on breaking up. The whole rock of this hill is of a curious compact and almost flinty kind, and if it were originally a deposited or sedimentary rock, it is difficult to imagine how the whole mass could have been so completely altered as to become quite the same from top to bottom through a thickness of seventy-five to eighty feet merely by the contact and heat of probably thinner trappean flows applied either above or below, or both; and there is nothing in the structure of the ground to lead to the

conclusion that this Antop Hill rock, in its present form, was ever overflowed, and surrounded by trap-rock; only its denuded surface being now exposed.

It differs greatly in appearance from any of the trap-rocks commonly found in the neighbourhood, and, as far as we know, is only a local variety of this rock. It has none of the appearances characteristic of a dyke, no walls nor joint-fissures such as dykes frequently present, running in the same direction as their strike; and the material is quite unlike any of the dykes usually found in these trappean rocks. It re-appears at Seoree with the same general aspect and is said to occur again, forming the rock called Cross Island in the harbour at a distance of several miles, but still directly in the line of strike. Taking this long range parallel to the general stratification of the Island, and the appearance of the same rock underlying the breccia south of Sion, into consideration, it seems most natural to suppose that this black jaspideous rock is a mass or flow of lava-like trap cut through by a fault which alters its level close to the burial ground on Antop Hill. The fault may perhaps have allowed its dip to change so as to have exposed it differently to the denuding forces, and thus have caused it to assume the form of hills to the south, while northward it makes the floor or basement upon which other hills of a different material stand.

Just to the north of where the above-mentioned fault is supposed to run, and overlooking the burial ground on Antop Hill, a higher elevation exposes in one place a very peculiar appearance in the breccia. The rock, elsewhere red, is here white, ashy looking, and tufaceous, enclosing white fragments which appear like portions of the black compact rock in a highly altered state; it has a very volcanic appearance, and is traversed by numerous hard and ferruginous strings and veins, is peculiarly open to the action of the weather, and apparently wears down under its influence to a red clay.

This rock is stated by Dr. Carter to cut across the other trap in its neighbourhood, and Dr. Leith informs us that it encloses tilted portions of the shale rocks said to occur just below it; but although the ground hereabouts was repeatedly crossed in different directions, none of the shales except those previously mentioned were observed by us, nor was anything seen to prove that the variegated rock occurs as an intrusive dyke; on the contrary, whether intrusive or otherwise, its appearance forming a little cliff or scarp along the brow of one hill between different kinds of trap above and below, widening out where the crest of the ridge has been lowered to its level by erosion, thinning away at one end beneath the Flagstaff Hill (the shape of which more strongly perhaps than any thing else bespeaks its stratification), and appearing to do the same in the other direction, where it is only traceable by the blocks, &c.,—which may have been separated from its scarp or outcrop, and now lie on the hill side a little below the level where it would probably run on beneath the solid scarp of hard gray trap which forms the crest of Race Hill,—all these circumstances unite in favour of its being a lenticular mass interposed between two of the beds or flows of the local trap.

Rocks near Parel.

The trap-rocks around Parel occupy a wider space than anywhere else in the Island; they are chiefly varieties of compact gray and amygdaloidal trap about Parel itself; the latter are more common, and they extend to the southward beyond Chinchpooglee towards the native town. The gray-trap is observable in greater force along the east side of this tract, but bands of it appear also immediately to the west of Parel: further west again the rock seems to be more amygdaloidal, and just at the edge of the flats some of the fresh-water beds appear at intervals in the low ground. They may be seen in the ditches along the Railway and at the south-east angle where the new road from Parel crosses it. Here they seem to be interstratified with alternating beds of amygdaloid and muddy looking ash.

On the east side of the Railway, about a mile to the south of this, some openings in connexion with the gas-works have been made just at the east edge of the flats, and these are found to contain gray and brown flaggy and shaly beds, with numerous large vegetable impressions between the layers; they would seem to undulate rather irregularly, in some places having a low westerly dip,* and close to them on the east numerous old quarries and tanks expose the amygdaloids associated with the gray-trap. Similar amygdaloid, ashy, and shaly beds may be seen in many spots between this and the Race-course, and would seem to extend, associated with gray-trap, past Byculla towards the native town. Other of the flaggy beds appear near the north-western and south-eastern corners of the Race-course, and there is good reason to believe that either these, or the rocks last mentioned, occur in many places, at no great distance from the surface, in the flats.

Mazagaon.

Between Mazagaon and the Race-course many openings in gray and amygdaloidal trap may be seen, but at Mazagaon itself, on the side of the hills overlooking the harbour, there is much soft decomposed ashy looking trap, of somewhat similar appearance to that beneath Rowla Hill. As it is variegated, pink and green, it also resembles the rock seen in the railway-cutting at Sion. Its relations to the adjacent rocks are not very evident, but as it is capped by a band of hard gray-trap, the probability is that like the other varieties of rock on the Island it also is interstratified.† Eastward of this and extending into the harbour

* Since this ground was inspected other openings have been made in the flats further west and on that side of the Bombay, Baroda, and Central India Railway; in these a coarse granular sandstone, which seemed to occur in very thick beds and the stratification of which was undiscernible, was found; it seems to be wholly made up of disintegrated trap, and doubtless is a part of the shaly series found close by. (A. B. W., November 1864).

† During some recent excavations at Belvidere and Mazagaon Hill the hard band of trap above was seen to curve considerably, descending the hill and again apparently re-assuming a horizontal appearance at its base—(From information supplied by Dr. Leith). The rapid removal of the hill by one of the Reclamation Companies has so much interfered with this place that the connexion of the hard stratum can no longer be traced.

are varieties of gray-trap and amygdaloid of very similar appearance to those seen elsewhere.

The narrow band of shales containing *Cyprides*, which occurs at Nowrojee Hill between two beds or flows of gray-trap, has been noticed by Drs. Carter and Buist, and also another (which from its position should be a higher band) appearing in Baboola Tank to the west.

The usual varieties of gray-trap extend from this locality to the Fort along the eastern side of the Island.

Colaba Islands.

The Islands of Colaba, united by causeways to the island of Bombay, are composed of varieties of dark and pale gray-trap, in some places resembling a crystalline greenstone. These trap-flows undulate, and are apparently nearly horizontal, but, taken collectively, seem to have a slight dip to the north of west. Large surfaces of these trap-rocks, sometimes containing small garnets and zeolites, are exposed between tide-marks on the Back Bay side of the promontory formed by connecting these two Islands. In a small unbuilt tank near the coal sheds, behind the Officers' quarters on the east side of the promontory, a thin band of nearly horizontal, shaly, and flaggy, beds was found appearing to incline slightly to the north of west; these do not exceed five feet in thickness; they much resemble the rest of the fresh-water beds, and they contain numerous small fragmentary impressions of plants, among which one bearing an obscure resemblance to a leaf was found.*

Columnar trap.

A group of basaltic columns is marked upon Dr. Carter's map off the shore of the Esplanade in Back Bay. These were not reachable on account of the tide, and although the traps of the Island are not generally columnar, other portions of the traps of Western India are too frequently so to render such an occurrence extraordinary.

* Information kindly given by Dr. Leith led to the finding of this place.

A small exposure of trap, we are informed by Dr. Leith, exists on Grant Road near the place where chunam kilns are marked upon the map.

As the flats are almost entirely occupied by recent and superficial deposits they will be mentioned subsequently, and we will now pass on to the Malabar ridge. The basaltic flows, which from end to end occupy the upper parts and western slopes of this ridge, are everywhere almost exactly similar, presenting far less variety in their composition than any of the other trappean rocks of the Island. The basalt is massive, compact, and blackish, very strong, hard and tough, with but a thin rusty coating on its most weathered surfaces. Dr. Carter marks some spots as columnar, and it is often intersected by curious hexagonally reticulated quartz or zeolitic veins, presenting sections on the surfaces of semi-detached blocks like those of basaltic columns, or the desiccation-markings frequently observed upon the surfaces of aqueous rocks, which are supposed to have been acted upon by the drying effects of sun and air. These may be frequently seen at Malabar Point.

Malabar ridge.

Further north, where the road from Bombay to Walkeshwur passes beneath the cliff upon which Castle Dangerous stands, the basalt is intersected by joints, leaving great pillars like enormous basaltic columns detached from the rest of the cliff, the intervening portions having no doubt crumbled away under the influence of the weather. Some of these, either owing to the same cause or some displacement of the softer strata beneath, have become inclined to one side or other; huge masses of polygonal or cuboidal form, doubtless separated in the same way, lie scattered about upon the slope at the foot of the cliff.*

Further northwards the bedding of the flows becomes more visible, particularly at the end of the hill facing the Vallade, and about its summit—the highest point in the Island, from which may be obtained a splendid view, including the whole of the Island of Bombay, the Islands

* Since the above was written many of these have been removed.

in the neighbourhood, the harbour and the fine mountains beyond.* At this place Malabar Hill proper ends; indeed the northern part is distinguished by the name of Kumbala Hill, but the same ridge, with a considerable interruption at the Vallade and a less one at the sluices, extends to Wurlee Point. Basalt of very similar character to that just now described may be found at low water about the little Island opposite to the Vallade, on which there is a Fakir's house; at Lovegrove, where the main drainage enters the sea; and all along Wurlee Hill, where its dip to the west gives a very regular and marked inclination to that side of the hill. Plate III is a view looking southwards from Wurlee Hill over the flats and the Vallade towards Kumbala Hill, the northern extremity of Malabar ridge.

At a little distance south of the village of Wurlee the basalt seems to lose its strongly basaltic character, or more probably other bands of concretionary, splintery, much weathered, and softer, trap beneath it become visible where the ground is low.

Shales near Back Bay.

Returning now to Malabar Point and proceeding along the shore of Back Bay, we find a reason for the abrupt scarp on this side of the hill in the occurrence of the fresh-water shales and flags. They appear first beneath the private road to the Governor's Lodge in a manner which suggests either that they thin out here naturally, or that a local depression in the whole group, including the overlying basalt, bends them downwards, so as gradually to disappear beneath the sea. From this point they appear in greater quantity as we proceed northwards, reaching in places a thickness of considerably more than 50 feet, without the upper part of the group being exposed owing to the covering of debris at the foot of the basaltic cliff.

* Near this place, at Mahalukshmee, the basaltic trap is rudely columnar.

Pass under Malabar Hill.

That these shales pass inwards beneath the basalt so as to form a large portion of Malabar Hill might be presumed from the external appearances of dip in both rocks, and from what has been already said of the general structure of the Island; this is, however, proved to be the case by the discovery of the shales in wells and such sinkings through the basalt on various parts of the hill. Dr. Leith observed them exposed in this manner along the upper road to the Governor's Lodge near the last large bungalow on that road before reaching the gateway of the Governor's compound. He also kindly furnished the following information :—

" Near the house lately occupied by Mr. Blay (close to where the height, 123 feet, is marked along the west shore of Back Bay), trap containing patches and angular fragments of shale was found in an excavation, from which also were taken pieces of the shale containing fossilized skeletons of frogs. Specimens of these shaly rocks may be seen in the parapet wall close by Castle Dangerous.

" Near this and at a short distance from the crest of the hill on the seaward side the trap was passed through in Mr. Cook's compound, and coarse shales were found beneath.

" In a well at the top of the long hill on the road from Chaopatee to Walkeshwur, and about 300 yards north of the entrance to the above-mentioned private road to the Governor's bungalow, 55 feet of shales were passed through and trap found beneath them. The shales were very fossiliferous, containing numerous skeletons of frogs, besides many plant impressions. As the height of the well at this place is not accurately known, a possibility exists that it may penetrate to a greater depth than the level of the sea, and thus reach a band of trap, weathered or ashy portions of which may be observed in situ along the shore." See also Dr. Carter's observations about this place, (Geological Papers on Western India, p. 143.)

In Dr. Buist's paper, page 171, Geological Papers on Western India, a foot note states that "a mass of diorite or greenstone, totally unlike the basalt of which the rest of the "ridge consists, was this season (1856) cut through on digging a well in a native garden "close by the entrance to the Government House grounds, at the further end of the village "of Walkeshwur. At the depth of 30 feet a pale-gray (alluvial) stratum of earthy looking rock was met with, exactly like that traversing Nowrogee Hill."

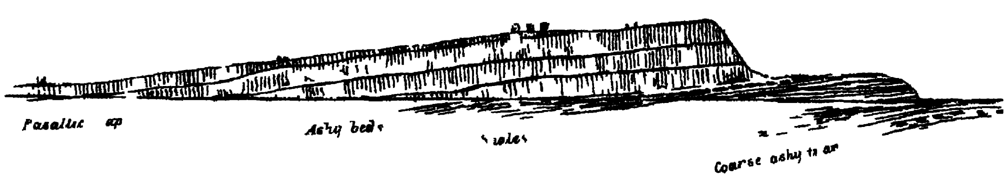
Those of the shale beds which we had an opportunity of examining were chiefly exposed along the shore below high water mark; they are

of light color, rest upon a coarse weathered trappean bed, and are much decomposed in places to a yellowish olive; they are very ashy in appearance, suggesting, as these rocks so frequently do, their being derived from trappean materials. They have a general low or undulating dip to the westwards, and contain, as usual, *Cyprides* and *plants*.

In the excavations being made at Chaopatee near this place for the reclamation of Back Bay, a considerable mass of trappean, flaky, deposited rock, containing large lenticular portions, is exposed; it has the usual westerly dip of 10° to 15°. Half a mile to the north-north-east of Chaopatee is the Gwala Tank, in which the shales also appear, and these, together with the associated ash, occur all along the eastern foot of Kumbala Hill, but there is considerable difficulty in the way of tracing them on account of the numerous compounds and the lower slopes of the hill being covered by detritus from above.

In one of the compounds on the end of the hill near Mahalukshmee, Dr. Leith informs us, the basalt was pierced by a well and the shales found beneath it; so that we may safely presume the structure of the hill to be such as the accompanying sketch represents :—

FIG. 1.—SECTION ACROSS MALABAR HILL.



Shales at Lovegrove;

At low water the little Island off the Vallade may be seen connected by a wide patch of dark rocks with the shore at Mahalukshmee, and long reefs also stretch from the Island towards Lovegrove Point. Upon examining these rocks near Mahalukshmee we cannot be surprised to find the flaggy fresh-water beds again lying nearly horizontal, but undulating a good deal, and to the westward, or in the direction of the general dip, overlaid, as usual, by the traps. The Island upon which the Fakir's house stands is higher than these horizontally undulating shales, and is composed of the overlying traps, which extending to the northward form the highest part and seaward side of Lovegrove Hill. At the sluices again the shales are exposed in the cut for the discharge of the main drain.

at the Sluices.

They undulate, as they do at the further end of the Vallade, the part seen being from the axis of a very low and open anticlinal westward, exhibiting a dip of

FIG 2—SKETCH SECTION, SOUTH BANK OF THE SLUICES

about 15° and less in that direction, but very little inclination to the east upon the other side of the curve. The shales seem to be thinner here than to the south, or else contain a considerable band of ash, which occupies the centre of the anticlinal curve. If the ash is to be looked upon as the lower limit of this band of shales, the thickness can only be about 30 feet, as the overlying trap with the same, or if anything a lower, dip, comes in at a distance of only a few yards to the west.*

The bluish-gray ashy rock which contains the patches of black shale is looked upon by Dr. Carter as intrusive, yet its appearance is not now like that of a dyke of any sort; on the contrary, a thin and probably lenticular band of dark olive and black shale appears to be interstratified with it and again overlaid by a considerable band of the ashy looking rock.†

The break through which the main drain passes into the sea is about 250 yards in width. Of this but a small portion is occupied by the shales on the south side of the drain, while they expand to the north—some irregularity, perhaps contortion, in continuation of the anticlinal shown in the figure, causing them to be exposed for a little way along a small cliff on the seaward side of the southern extremity of Wurlee Hill, but they pass beneath the basaltic trap of the hill within a few yards. Such irregularities in the outlines of boundaries of erosion are

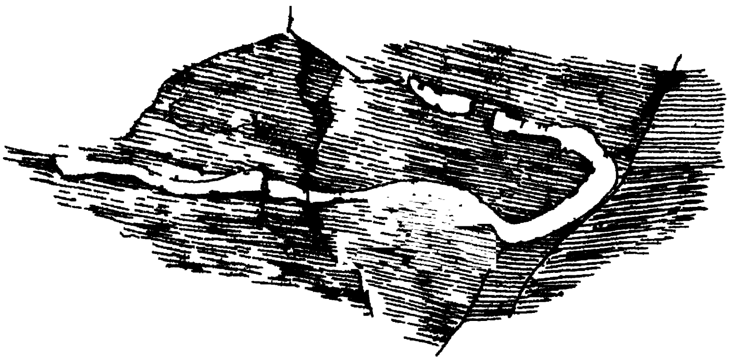
Wurlee Hill.

* The description of this locality given by Dr. Carter, who probably saw it to better advantage than ourselves, is very accurate. (See Papers on Western India, page 129).

† We have no reason from what is seen at the sluices to conclude that the base of the shales is exposed, and if the igneous rock which forms the centring of the anticlinal arch was supposed to have arrived at its present place in a sufficiently plastic state to flow, it might have taken up on its way projecting portions of semiconsolidated shale such as would be left by the erosion, which no doubt acted upon the surface over which it flowed. Such circumstances as caused the deposition of all of these shales would account for the occurrence of the dark olive and black shale layer containing *Cyprides*, which overlies the lower trap, and another flow, somewhat resembling the first, would produce all the appearances seen beneath the black shales represented in the cut.

as common as the undulations of the ground which produces them, and when any irregularity in a vertical direction occurs along the line of junction, this becomes, as a matter of course, exaggerated in plan. The shales here appear to have been so much crushed that it is almost impossible to follow their stratification. Appearances like those which occur here are frequently seen in fissile beds upon the slopes of hills, and are generally attributed to a superficial slippage called 'the fall of the hill.' A similar effect might perhaps have been produced by the weight of the overlying trap when it assumed its sloping position together with the shales, or when the overflow took place. The accompanying is a sketch of the appearance presented by part of a thin hard band which occurs amongst the softer shales at this place*,—the end of Wurlee Hill.

FIG 3 —HARD BAND OF BROWNISH WHITE SHALE IN SOFTER BEDS.



* The shales all terminate so suddenly here that a fault is suggested by their ending, but the locality does not favor the tracing of it, so that the above has been considered the safest conclusion to arrive at from the evidence.

To the northward of this place the shales do not appear again on the seaward side of Wurlee Hill, but they may be frequently seen in the tanks, &c., at its eastern foot, in the same relative position as beneath Malabar Hill.* As is usual they have a slight dip to the westward, their outcrop following the irregularities in the form of the ridge and outcrop of the traps as elsewhere. This Wurlee ridge sinks where Wurlee Point commences, and in the lower ground some softer beds than the basaltic trap overlie the shales. The latter are well seen with their prevailing westerly dip of 15° to 20° in some deep open wells just south of Wurlee Fort. Further to the north near the Point, soft, red, ashy-looking, breccia appears upon the shore overlying soft, yellowish, and light-colored shales, of which 30 or 40 feet are exposed, the whole dipping at 12° a little to the south of west. The end of the Point is composed of the hard basaltic trap, with an undulating westerly dip.

Wurlee Point.

The flats, as might be expected, are extensively occupied by alluvium brought doubtless from the main land and deposited in the slackwater of currents setting between the islets, which, after elevation, became the hills of Bombay Island. Littoral deposits also occur, but none of the accumulations seem to retain their thickness or color over the whole of the flats if we except the recent conglomerate. The principal of these alluvial and littoral deposits are the brown kunkury clay so often

Flats of Bombay.

* Dr. Carter, at page 143 of 'Papers on Western India' states that everywhere underneath Malabar ridge the shales occur as an anticlinal; nothing to support this was seen except at the sluices, where somewhat of an open anticlinal curve has been described, but this much more resembles the undulating character of the beds outside the Vallade on the landward side, and on the seaward the general tendency of the Bombay rocks to dip westward. Dr. Carter gives the angles on both sides of this anticlinal as 40°, but this from what is now exposed seems much too high. Some false bedding or oblique lamination in the black shales appears to dip at a higher angle than the rest to the westward, but the general inclination, although unsteady as now seen, may be more safely estimated at below 20°.

seen along this part of the coast of Western India; a kind of blue clay containing mangrove roots, which may be a variety of the other; and the recent beach conglomerate (well called by Drs. Carter and Buist* littoral shell-concrete) which overlies the clay.

Dr. Carter seems to class all the clays together, and says "the color is brown above, blue below, and then yellowish;" the greatest thickness mentioned by him is 10 feet. The beach conglomerate or shell-concrete, he says, is found principally on the northern and southern

Shell-concrete.

shores of the Island, with an extreme depth of 20 feet, but it once existed at a place called Phipp's Hortos† almost in the centre of the Island, and it may be seen also near Seoree Fort, and occasionally in numerous other places about the flats. The shells which it contains are all of recent kinds found upon the neighbouring shores.

Dr. Carter mentions the following genera, several of which we have also observed, *Cardium, Tellina, Turbo, Cerithium, Nerita, Trochus, Turritella,* and *Placuna.* Dr. Buist, who seems to have given the superficial deposits of the Island a great deal of attention, states that the lowest alluvium is the yellow kunkury earth, which, owing to the changes of level previously noticed, now occupies and forms the soil of many of the higher portions of the low lands, where red earth, (*lal muttee* of the natives, decomposed trap, &c.,) does not take its place: over this he places the blue clay containing selenite (sulphate of lime) and kunkur (impure

* Geological Papers on Western India, page 159.

† Attention has been called by Dr. Leith to a deposit of gravel near the sluices containing rolled and, as he suggests, transported pebbles. It was not noticed on the ground, and the pebble which Dr. Leith kindly showed us from it could not be identified with any very distant rock. Erratics are alluded to by Dr. Buist, at page 188 of his paper previously referred to, but we have seen nothing to establish the existence of any masses transported from a great distance; indeed this could hardly be expected, and all the fragments which go to make up the recent formations may have been derived from more or less local or neighbouring localities.

carbonate of lime), enclosing mangrove roots and masses of oyster shells; and above this is the littoral shell-concrete, sometimes loose in texture and sometimes very compact with all the shells replaced by crystalline carbonate of lime.

Red-earth.

As the most recent, or one of the most recent superficial accumulations, it will be sufficient to observe of the red-earth that it is plainly the result of the atmospheric decomposition of the trap which, under slightly different circumstances, or where decomposition has not proceeded for so long a time at one spot, results in the coarser accumulation called 'moorum'.

Blown sand.

Blown sand occupies a considerable space along the coast near Mahim, forming a low cliff or scarp; it appears to have been prevented from travelling further inland at a somewhat remote period by vegetation. A graveyard in the sandy scarp exposed in the monsoon of 1854, and covered by several feet of the sand, as is mentioned by Dr. Carter (page 161 of Geological Papers on Western India), indicates the antiquity of Mahim as an inhabited locality.